547
BralSub
88112

THE
ASIATIC SOCIETY OF BOMBAY
TOWN HALL, BOMBAY-1.

Digitized with financial assistance from the
Government of Maharashtra
on 09 March, 2016

THE

SUBJECT MATTER

OF A

OURSE OF TEN LECTURES

ON SOME OF THE ARTS CONNECTED WITH

ORGANIC CHEMISTRY,

IVERED BEFORE THE MEMBERS OF THE ROYAL INSTITUTION
IN THE SPRING OF 1852.

BY

WILLIAM THOMAS BRANDE,

D.C.L., F.R.S., M.R.I., ETC., ETC.

Honorary Professor of Chemistry in the Royal Institution of Great Britain.

ROYAL INSTITUTION OF GREAT BRITAIN CHEMICAL SOCIETY

RANGED, BY PERMISSION, FROM THE LECTURER'S NOTES, LENT FOR THE OCCASION,

BY

J. SCOFFERN, M.B.,

Late Professor of Chemistry at the Aldersgate College of Medicine.

CCB i 6

88112 a1

LONDON:

)NGMAN, BROWN, GREEN, AND LONGMANS.

MDCCCLIV.

854

J 47
Bra/Sub
88112

LONDON:
PRINTED BY PETTER AND GALPIN, PLAYHOUSE YARD,
ADJOINING THE "TIMES" OFFICE.

PREFACE.

INDEPENDENTLY of the abstract value of lectures on a subject so important as that of *Organic Chemistry as applied to the Arts and Manufactures*, by a gentleman of Professor Brande's position and experience, there is yet another kind of interest attached to the following: *they were his last.*

After more than forty years active devotion to the science with which his name is so honourably associated, as Professor of Chemistry at the Royal Institution, Professor Brande chose the subject of *organic chemistry in its application to the arts and manufactures* as that of his farewell course. The following pages contain a re-production of that series.

The claims, both real and collateral, of the lectures in question, to a wider sphere of diffusion and utility than is limited by the members of the Royal Institution, influenced me (having first obtained the lecturer's sanction) to give publicity to them in a literary shape. With the furtherance of this object in view, Professor Brande kindly supplied his notes, and contributed every aid, short of taking upon himself the responsibility of publication; a responsibility for which the editor alone is answerable.

The reader will not fail to comprehend that my own relations to this volume are peculiar. Proud as I must ever be that the distinguished lecturer confided his notes to my guardianship, studied in every respect to facilitate the execution of my task, and, in short, bestowed an active solicitude, for which I am not the less deeply grateful that I may not advert to it more particularly here,—yet certain difficulties to which ordinary productions of literature are not amenable have presented themselves; amongst these, paradoxical as the statement may appear, the very facility in dealing with his subject, manifested by the lecturer, has proved not amongst the least. A mind in which the

whole subject of discourse was so well arranged as his, needed the aid of but few written notes; and from this skeleton, so to speak, the entire subject had to be constructed—the editor's own remembrance of the lectures themselves furnishing the necessary details. I venture to express the hope, however, that on the whole the execution of the task is no less faithful than the attempt has been conscientious; and absolving altogether the lecturer from all demerits, whether of commission or of omission, that criticism may hereafter discover in this volume—I thank him thus publicly for all the kindness and courtesy displayed in facilitating its appearance.

CHEMICAL LABORATORY AND ASSAY OFFICE,
33, Great St. Helen's, Bishopsgate-street,
July 29, 1854.

SYNOPSIS OF THE LECTURES.

INTRODUCTION TO LECTURE I.—ON DYEING.

HISTORY OF TEXTILE MATERIALS TO WHICH DYE-STUFFS ARE APPLIED.

PAGE

History and Natural History of Silk.—Its use limited by law in ancient Rome; its manufacture mentioned by Aristotle; the silkworm indigenous to China; strange opinions respecting the source of silk; account given by Pliny; embassy of Marcus Antoninus to China to collect information; exorbitant price of silk in the reign of Justinian; introduction of the silkworm by stratagem into Europe; its culture confined to the Eastern Empire 600 years; introduced into Western Europe by Roger, King of Sicily; encouraged by the Moors in Spain; silk manufacture first attempted in France under Louis II.; silk worn by the higher classes in England soon after the conquest; its manufacture introduced by emigrants from the Spanish Netherlands, and by French Protestants on the Revocation of the Edict of Nantes.... 1-11

Botany, Natural History, and History of Cotton.—Its botanical position; various species of the genus; practical division; geographical distribution; Hindoo manufacture; Indian muslins; antiquity of the cotton manufacture; etymology of the word "cotton;" first introduced into Europe by the Saracens; inferiority of the raw produce of Hindostan; description; mode of separating the seeds in North America..... 11-20

LECTURE I.—ON DYEING.

Successful application of chemical science to the art of dyeing; classification of materials; substantive and adjective colours; advantage possessed by the latter; perfection of the art in ancient Egypt; testimony of Pliny; antiquity of the use of indigo in India as a dye-stuff; used also by the Mexicans; Tyrian purple dye; the knowledge of its process lost during many centuries; re-discovered in 1683 in this country; chief adjective colours known to the Greeks and Romans; Britons and Gauls; dyeing

PAGE

agents introduced after the discovery of America; recent development of the art by means of chemistry; mordants; "Saxon blue;" experiments with silk, cotton, and worsted; the safflower; alumina; discovery of the "Bow-dye," a rich scarlet colour from cochineal; salts of iron and Prussian blue; "*bleu de vapeur;*" discharge-work..... 21-49

LECTURE II.—ON THE OPERATIONS INVOLVED IN BLEACHING.

Bleaching of cotton; chlorine; its nature and power as a bleaching agent; experiments; advantages of the solubility of chlorine in water; mode of effecting it; chloride of lime, or bleaching powder; process of its manufacture; its use in calico-printing; meadow bleaching; peculiar conditions of the atmosphere, &c., favourable to open air bleaching; discovery of *ozone;* doctrine of "allotropism;" exemplifications of the doctrine—sulphur, phosphorus, oxygen; agency of electricity in effecting allotropic changes; ozone as a bleaching agent; sulphurous acid as a bleaching agent; benefits resulting from the application of chemical science to the process of bleaching..... 50-71

LECTURE III.—ON CALICO-PRINTING.

Extensive, refined, and minute acquaintance with numerous arts and sciences necessary to a calico-printer; art of applying colours topically; objects to be attained; "block-printing;" "stencilling;" "resists;" mordants and discharges: variety of tints produced by the use of alterative mordants; theory of "ironmoulds;" beautiful method of topically applying Prussian blues; the mechanical processes of calico-printing; economy of time and labour effected by recent improvements; manufacture of bandanna handkerchiefs; discharge by agency of chlorine; indigo; difficulty of fixing indigo-blue figures on a white ground; ingenious contrivance for overcoming this difficulty; description of indigoes of various countries; conclusion..... 72-93

LECTURE IV.—ON GELATINE, TANNIC AND GALLIC ACIDS, AND THEIR APPLICATIONS.

Gelatine the basis of leather; diffusion of gelatine throughout the structure of animals; its use in nutrition; chemical tests for gelatine; sources of gelatine; dried gelatine; the manufacture of leather; tannin; table of substances containing tannin; tannic acid; method of preparing it; gallic acid; its preparation; effect of heat thereon; theory of tanning; tanning agents; oak-bark; sumach; catechu; outline of the operation of tanning; devices for facilitating the process..... 94-116

INTRODUCTION TO LECTURE V. ON SUGAR.

SUGAR AND THE SUGAR-CANE.—THEIR HISTORY AND NATURAL HISTORY.

PAGE

History of the sugar-cane and sugar; sugar the last imported of all oriental products; not mentioned in the early records of Western Asia; the "Indian salt" known to the Greeks and Romans, probably sugar-candy; the sugar-cane seen by Nearchus, admiral of Alexander the Great; scarcely known in Europe until the thirteenth century; introduced into Spain by the Saracens, and planted in Andalusia; the growth of sugar especially encouraged by the Portaguese; a specimen of the real sugar-cane brought from China by Marco Polo; its culture extensively adopted in America early in the sixteenth century; sugar first refined in England in 1659; unaccountable prejudice against it; enthusiastically advocated by Dr. Slare; his testimony to its excellences 117-130

Natural history and botany of the sugar-cane.—Botanical description and position; sugar-mills..... 130-133

Other sources of cane-sugar in addition to the cane. The sugar-maple; the various palms; beet-root; importance of the date-palm; mode of extracting its sugar; beet-root as a source of sugar; annual consumption of sugar in France and England; process of manufacture in Belgium; the *monte-jus; cone de Lembecg;* process of filtration; spontaneous evaporation; description of the loaf turbine 133-145

LECTURE V.—ON SUGAR AND ITS MANUFACTURE.

Importance of the subject; extent and value of the sugar manufacture; loss in the process of extraction; what is sugar? grape-sugar and cane-sugar; process for producing grape-sugar; test for grape-sugar and cane-sugar; changes effected by heat; amount of charcoal in sugar; chemical composition of sugar; numerous causes of the large destruction of sugar in course of manufacture; outline of its manufacture; sugar-mills; molasses; processes of evaporation and claying; muscovado; the plan adopted in Cuba, Brazil and Spain; refining; "blowing up;" use of lime-water; filtering apparatus; decolourising property of animal charcoal; method of decolourising the sugar solution; charcoal washing; the phenomenon of ebullition; the vacuum-pan; its use explained; filling out; washing; claying; liquoring; facing and nosing-machines; contrivances for facilitating drainage; turbines; removal of impurities by the sub-acetate of lead 146-205

Practical instructions for using the vacuum-pan 206

Table representing the specific gravity of solutions of sugar of various strengths 232

Table of the density of solutions of sugar according to the scale of Beaumé 232

LECTURE VI.—ON WOODY FIBRE.

PAGE

The subject connected with many important arts; lignine analogous to starch and sugar; its composition invariably the same; method by which it may be procured; results of the application of heat; conversion of lignine into grape-sugar; gun-cotton; its unmanageableness; M. Claussen's cottonising process; Mercer's corrugating process; woody fibre converted into bread; slow chemical changes incidental to woody fibre; Kyanised timber; Sir William Burnett's patent; best time for felling timber 233-246

LECTURE VII.—ON THE CHEMISTRY OF FATTY BODIES:

INVOLVING THE MANUFACTURE OF SOAP AND CANDLES.

General binary division of the subject; volatile, or essential, and the fixed oils; the former, more vapourisable than the latter; yield essences; quantitative relations of the fixed oils; compound nature of fixed oils and fats; each is really a *salt*, compounded of an acid with a base; proximate composition of oils and fats; ultimate components and relations of glycerine, stearine, and stearic acid; theory of the manufacture of soap and candles; deceptive nature of many kinds of soap; valuable chemical property of soap; palm oil and composite candles, their superiority to the old tallow candle; inconveniences of the latter, arising from its compound nature and imperfect wick; use of wax and spermaceti; researches of M. Chevreul; publication of his views, and their practical application to the candle manufacture; prize offered by the Paris Society of Encouragement; successful production of a superior candle by MM. Motard and Milly, equal to wax; and subsequently by Messrs. Price and Co., by another process; process of the manufacture of composite candles on M. Chevreul's scheme; Price's process; inconveniences arising from the tendency of the fatty acids to crystallise; contrivances for improving the wick; paraffine as a substitute for fats or fatty acids; sources of paraffine—Irish bog land and *British* coal; methods of obtaining it..... 247-272

APPENDIX TO LECTURE VII.

Collateral Influences of the Discoveries of M. Chevreul..... 273-286

LECTURE VIII.—ON HYDROCARBONS.

Compounds of hydrogen and carbon extremely numerous; all strictly organic; atomic composition of the principal hydrocarbons; several of them identical in chemical composition, but dissimilar in constitution and density; olefiant gas, naphtha, and naphthaline, illustrations of gaseous, liquid, and solid hydrocarbons; relations

PAGE

of oleflant gas and alcohol; use and value of chemical symbols; combustible peculiarities of some hydrocarbons illustrated; naphtha; benzole; camphine; hydrogen; complex nature of pit-coal, and necessity for its purification in the manufacture of coal gas; importance and extent of the gas manufacture; caoutchouc, its chemical composition and properties; vulcanised india rubber; extraordinary influence of sulphur in its preparation; gutta percha, its source and peculiarities; applications of gutta percha; process of purification 287-312

LECTURE IX.—ON NITROGENIFEROUS OR AZOTISED SUBSTANCES.

These substances used in many of the arts and manufactures; nitrogen an essential element of the blood and animal tissues, and, therefore, in food; negative peculiarities of nitrogen in its isolated state; in chemical combination it is pre-eminently active and energetic,—as in acids, poisons, and gunpowder; its combinations with oxygen; sources and properties of nitric acid; its characteristics and intense chemical powers; applicable to many purposes of the arts; an ingredient in gunpowder: compounds with hydrogen; ammonia; obtained by the destructive distillation of organic products containing nitrogen; mode of collecting pure ammonia; its characteristics; properties in combination; curious case of its formation by Dr. Hare; nitrogen supplied to the vegetable kingdom in the form of ammonia; mutual dependence of plants and animals; elaboration of materials in the vegetable kingdom for the support of animal life; resolution of compounded principles in the animal system into more simple forms for the food of plants; salts of ammonia; their importance as manures; cyanogen and its compounds with nitrogen; Prussic acid; Prussian blue; fulminating compounds; reflections on the sources of ammoniacal and cyanic compounds .. 313-347

LECTURE X.—ON THE PHENOMENA AND PRODUCTS OF FERMENTATION.

Various species of fermentation; no vegetable juice subject to vinous fermentation that does not contain sugar, or some other principle capable of conversion into sugar; glucose or grape-sugar the only kind susceptible of fermentation; conversion of a portion of the starch of barley into gum and sugar by malting; formation of diastase in malting barley; remarkable power of diastase to convert starch into gum or sugar; influence of temperature; pale, amber, brown, or black malt, how produced; process of brewing; use of the hydrometer; hops, their influence; substitutes for hops; adulterations; phenomena of fermentation; wines; grape-sugar the source of alcohol in wine by fermentation; grape must

PAGE

ferments naturally, without the addition of yeast or any other ferment; this the result of the presence in the grape of a nitrogeniferous principle, the contact of which with the oxygen of the air causes fermentation to supervene; comparison of the constituents of wine and those of the grape; colouring matters; changes undergone in the cask and in bottle; diseases of wines; quantity of alcohol in different wines, beer, and spirituous liquors; theory of fermentation; germinating globules of yeast; their activity; pure alcohol, how obtained; its characteristics; comparison of fermented and distilled alcoholic liquors; the latter more deleterious than the former; composition of alcohol; its relations to other, olefiant gas, and ethyle; acetous fermentation; relations of alcohol to acetic acid, and of acetic acid to ethyle; concluding remarks and reflections 347-382

INTRODUCTION TO LECTURE I.

ON DYEING.

HISTORY OF TEXTILE MATERIALS TO WHICH DYE STUFFS ARE APPLIED.

HISTORY AND NATURAL HISTORY OF SILK.

THIS beautiful material, now so common—its use restricted to no social class—its price compatible with the means of all except the very poorest—was but little known in Europe until the age of Augustus; at which period tissues of this material were sold for an amount of gold equal to their own weight. This extreme value had a strong tendency, as may be inferred, to limit the use of silk to the very richest classes of society; nevertheless, the desire to clothe themselves in the beautiful material was so strong, that sumptuary laws were passed, at various times, in Rome, to restrict the employment of silk. Thus, in the reign of Tiberius, the use of silk (*oriental sericum*) was limited, by the laws of the Senate, wholly to women of rank. The use of the material by men of any social grade was considered as a mark of effeminacy, and was accordingly interdicted. This prohibition, however, extended only to the densely woven oriental silk tissues—satins, pro-

bably, or something of that kind. Besides which, civilized Europe obtained another description of silk, from a second source, the island of Kos; where a woman, named *Pamphila*, had, at a period long before the time of Aristotle, discovered a plan of unravelling the thick and heavy silken tissue of the East, and manufacturing the thread into a lighter material. Some idea of the estimation in which silk was held, and the price it commanded at Rome, in the third century after Christ, may be gathered from the circumstance, that amidst the other extravagant enormities of the Emperor Heliogabolus, it is recorded as a fact worthy of special comment, that he clothed himself with a robe made altogether of silk, without any admixture, and thence called "Holosericum." This was in the beginning of the third century. Towards its latter part the value of silk does not appear to have lessened, since we learn that the Empress of Aurelian having entreated her husband to give her a robe of silk, he, Emperor though he was, declined, on the plea of not being able to afford it—inasmuch as the robe could only be purchased at the rate of its own weight in gold! Aristotle alludes to this manufacture under the name of *bombykia*, or stuff produced from the "bombyx" (silk-worm). He lived in the fourth century before Christ, and notices the process in a manner suggestive of the inference that, at his epoch, it had already been a considerable time in existence. Connected with the natural history of silk, it is only just to the scientific character of Aristotle, to observe, that he appears to have

had a more correct notion of the nature of the material than, not only his contemporaries, but authors even of a later date. Aristotle distinctly refers silk to the bombyx, and gives a more correct account of the silk-worm than is to be found in the works of any other ancient author. He describes it as being "a horned worm, which passes through several transformations, and produces bombykia." It is not difficult to account for the superior correctness of Aristotle in this matter. When Alexander the Great set forth on his Asiatic conquests, he took with him a sort of scientific brigade—a troop consisting of 1000 men, whose sole duty it was to collect natural curiosities. Their whole time being spent in angling, hawking, and collecting botanical and mineralogical productions, the result was a rich museum of specimens, extending the bounds of knowledge in the department of natural history. This scientific brigade of Alexander was suggested by Aristotle, for whose immediate benefit the task of collecting was performed: hence it is not a matter of wonder that Aristotle should have given a better account of many oriental products than was accomplished by other ancient naturalists. Aristotle's description of the silk-worm, nevertheless, does not include the place of its native production. There is abundant testimony, however, from other sources—some of which will hereafter fall within the sphere of our inquiry—for arriving at the conclusion, that China is the region of the East to which the silkworm was indigenous. During the period of nine centuries sub-

sequent to the time of Aristotle, we have—furnished by different authors—accounts of silk altogether incorrect. Some writers described it as a fleecy substance, growing upon trees: amongst these authors is Virgil,

"Velleraque ut foliis depectant tenuia seres."

Others describe it vaguely as the "product of the bark of trees," or of "flowers." Amidst all this uncertainty there is yet recognisable a certain glimmering of truth. Vague accounts had doubtless been transmitted to these naturalists, of the silk cocoons depending from mulberry trees, a supposition which easily furnishes the key to the source of confusion.

The account of silk handed down to us by Pliny is singularly embarrassed. By a curious perversion of ideas we are informed in one place that the bombyx (silk-worm) was a native of Kos; in another place, that it was indigenous to Assyria. He also tells us, that the stuff which the Roman women unravelled and wove "after the manner of the people of Kos," was a fabric made from a woolly substance combed by the Seres (Chinese?) from the leaves of trees.

Thus it seems that silk only found its way into Europe by small quantities at a time, and at irregular intervals. The exact locality furnishing it was unknown, further than the determination of its correspondence with some land in the far East beyond India and Persia, and to which the term "Serica or Sereinda," or land of the "Seres," was vaguely applied.

There can be no doubt that the land thus vaguely indicated corresponded with China; for, independently of reasons founded on terms and geographical indications, we have more direct testimony. In the second century an embassy was despatched to the land of the Seres by the emperor Marcus Antoninus, chiefly with the object of collecting information regarding silk, and reducing the commerce in that article to a state of greater certainty than had been achieved hitherto. The embassy proceeded by way of Egypt and India, and finally arrived in China, as we are given to understand, by the records of the Chinese historian "Ven-hoen-tung." Even at this remote period the Chinese seemed to have been guided, in their political relations with foreign countries, by the same sentiments they have maintained to this day. The embassy was fruitless as to direct results, and the very nature of silk was so veiled in obscurity, that the embassy, on its return, added little or nothing to the stock of European information already existing on this subject.

The Romans of the eastern empire were still more luxurious than their predecessors. Coexistent with further necessity for silk, was a diminished supply of that material, on account of the frequent wars between the Persians and the Romans, which interrupted the flow of commerce from China to western Asia and Europe. In the reign of Justinian the price of silk had become so exorbitant, that there seemed a probability of its speedily going out of use altogether. In

order to remedy this excessive dearth, Justinian adopted an expedient common enough then, and indeed at much later periods. He attempted to fix a price at which silk should be sold by the merchants; thus preventing the latter from realising, as he thought, usurious profits by their monopoly. As might have been anticipated, an enactment so opposed as this was to the first principles of political economy, tended still further to lessen the importation of silk. At the epoch in question the silk-worm itself was introduced into the Byzantine empire by the following stratagem.

Even so early as the epoch of Justinian, Christianity had advanced to such an extent that several Christian churches were established in various parts of eastern Asia. Christianity had taken root, not only in India, but in China, or the country of the Seres. Two Persian monks, who happened to be attached to a church in the latter region, succeeded in penetrating the mystery which had so long environed the natural history of silk. They proved indubitably, that although collected from trees, as many ancient authors had asserted, silk nevertheless was the production of a caterpillar. Masters of this knowledge, the Persian monks travelled to Constantinople and made known the cherished secret to the emperor. It is not difficult to imagine, that on this information being communicated, the desire of obtaining the valued insect ran very high. The monks so ingratiated themselves into the favour of the emperor, that a large reward was offered as an inducement for

them to return, and bring to Constantinople, if possible, living specimens of the valuable insect. Accordingly the monks returned to China; but the means of fulfilling the object of their mission, of bringing away living specimens of the silk-worm, were not so obvious. Not only were the silk-worms guarded by the Chinese with great care and jealously, but the monks soon found that even if they could possess themselves of the living insects, the latter could not be transported to their final destination for want of their special food, *i. e.*, leaves of the mulberry tree. At length the idea occurred of clandestinely secreting a few silk-worms' eggs in the hollow of a cane. This plan was accordingly put in operation. A few eggs being inserted within the hollow of a walking cane, the pious monks bade adieu to China, hastened to Constantinople, and presented to Justinian the valued prize. In due time the eggs yielded caterpillars; and from this original stock has the whole of Europe been supplied with silk-worms. It so happened that the climate of many parts of the eastern empire, particularly Greece, was very congenial to the development of the silk worm. Its culture at once became a subject of imperial monopoly; and, curiously enough, the emperor Justinian had no sooner become himself a manufacturer of silk, than the price at which he sold his manufactured material was considerably higher than the price he had formerly stigmatised as usurious when the working of silk was free. During a period of about 600 years, the European culture and manufacture of

silk was wholly confined to the eastern empire: a more striking proof could not be cited of the social and political torpor of those dark ages. To the inhabitants of western Europe, the nature of silk was almost as great a mystery as when its culture and production were confined to China; nor did its market value fall so considerably as might have been expected. Indeed, at no time did the culture and the manufacture of silk become so much an object of legitimate commerce with the eastern empire, as of imperial ostentation. The material of silk was embarrassed with restrictions, sumptuary laws, and penal enactments, just in the same manner as the Tyrian purple had been; and so completely effectual was the policy in rendering silk a luxurious curiosity, that even so late as the year 790, Charlemagne sent two silken vests as an appropriate gift to the king of Mercia.

For the introduction of silk, and its manufacture, into western Europe, the world is indebted to Roger, king of Sicily, who, having invaded the eastern empire, overran its provinces, and despoiled Athens, Thebes, and Corinth—he made prisoners of some silk weavers, and compulsorily settled them in Sicily, where the insect thrived well and the manufacture flourished. Within a period of twenty years after the first establishment of the foreign artisans, the silk tissues of Sicily had become celebrated throughout Europe. From Sicily the new culture became disseminated into Spain and Italy, Spain appearing to have taken precedence; in

which country, especially its southern provinces, Valencia and Andalusia, under the Moorish sway, the manufacture of silk long continued to flourish. Granada became especially celebrated for its silk. When that province was conquered by Ferdinand, the Moorish silk manufactories were found to be in full operation. Subsequently, under Christian rule, Granada continued long celebrated for its silken fabrics, nor has the pre-eminence of that city in the same branch of manufacture been totally eclipsed, even at the present day.

The rearing of silk-worms, and the manufacture of silk, were first attempted in France, during the reign of Louis II., who obtained workmen from Genoa, Venice, and Florence, and settled them at Tours, under very extensive privileges, in the year 1480. The new branch of manufacture, however, was not then successful. It did not take firm root in France until the reign of Francis I.

The wearing of silken garments by the higher classes was adopted in England soon after the Conquest; as may be inferred from the statement, duly authenticated, that, in the year 1251, on the occasion of celebrating the marriage between Margaret, daughter of Henry III., and Alexander III., of Scotland, 1000 English knights appeared in "*cointises*" of silk. At this period, however, the use of silk was entirely confined to the highest classes, and even amongst them it was very rare. Indeed, even so late as the reign of Henry VIII., this monarch, we are informed, only occasionally wore silk stockings;

and his daughter Elizabeth was scarcely more fortunate in this respect during the beginning of her reign. At length, however, chance threw in her way a pair of silken stockings, of Spanish make, which she became so enamoured of, that in future she would consent to wear nothing else. Still later, in the reign of Edward VI., the fact is thought worthy of record, that Sir Thomas Gresham presented the monarch with a pair of silk stockings.

The first establishment in England of silk manufacture was shortly subsequent to the year 1585, and consequent on the seeking of an asylum in England by certain silk-weavers of the Spanish Netherlands, driven from their native country by the enormities of the Duke of Parma, who, having taken Antwerp by storm, after an obstinate resistance, consigned the inhabitants, during three days, to indiscriminate slaughter, and the city to destruction.

Soon after the first introduction of the silk manufacture, or, speaking more precisely, towards the latter part of the 16th century, England began her career of mechanical adaptations to the industrial arts, in which she has ever since been unrivalled. One of our first native mechanical inventions of this kind was made by the Rev. William Lea, of St. John's College, Cambridge. It was a loom for the knitting of silk stockings. The inventor was slighted at home, and, emigrating in disgust, took refuge in France; but the invention was at once applied, and English silk stockings soon became the cynosure to

which the eyes of foreigners desirous of possessing that luxury were turned. As regards the manufacture of other articles of silk, we are indebted for their introduction also to a memorable persecution, *i.e.*, the revocation of the edict of Nantes, in consequence of which numerous French protestant weavers, bidding adieu to their homes, took refuge in England. Having established themselves in Spitalfields, they originated the manufacture of silk, which has ever since characterised, and remained the prominent feature of, that metropolitan locality.

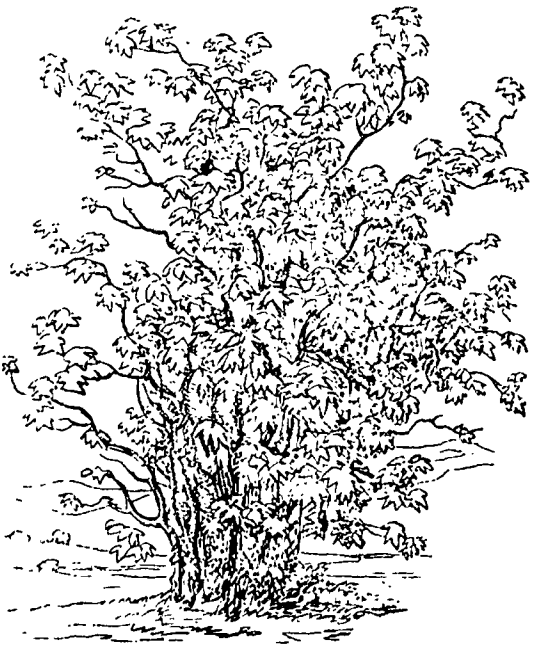
BOTANY, NATURAL HISTORY, AND HISTORY OF COTTON.

The substance *cotton* is the woolly denticulated fibrous material enveloping the seeds of various species and varieties of the genus "*Gossypium*," belonging to the natural order "*Malvaceæ*." Linnæus recognised five species of Gossypium, and designated them as follows :—

1. G. herbaceum.
2. G. arboreum.
3. G. hirsutum.
4. G. religiosum.
5. G. Barbadense.

Lamarck, in the Encyclopédie Méthodique, extends the species to eight; Cavanilles and Willdenow to ten. The species of Willdenow are the following :—

1. G. herbaceum
2. G. Indicum
3. G. micranthum
4. G. arboreum
5. G. vitifolium
6. G. hirsutum
7. G. religiosum
8. G. latifolium
9. G. Barbadense
10. G. Peruvianum



Shrub Cotton (*Gossypium religiosum*).

The claim of many of these to the rank of *species* is by no means well established, for all the cotton tribe are prone to run into varieties, under the united influence of climate and culture. Practically regarded, the best division is that of herbaceous, shrub, and tree cotton, of

which the herbaceous is the most useful. A representation of each is subjoined.

TREE COTTON (*Gossypium arboreum*).

The cotton plant, under one of its various forms, is indigenous to many of the warm climates, especially India, Egypt, and the warmer parts of America. It

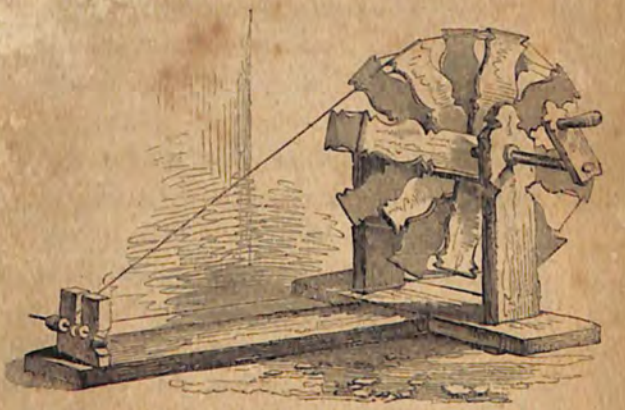
thrives best in sandy soils, not far removed from the sea. Marshy tracts are very unfavourable to it, and the crop is scarcely more to be depended upon than that of the vine.

The Hindoos have manufactured cotton cloth from time immemorial, and the operation of imprinting the white tissue has also been known to that ingenious

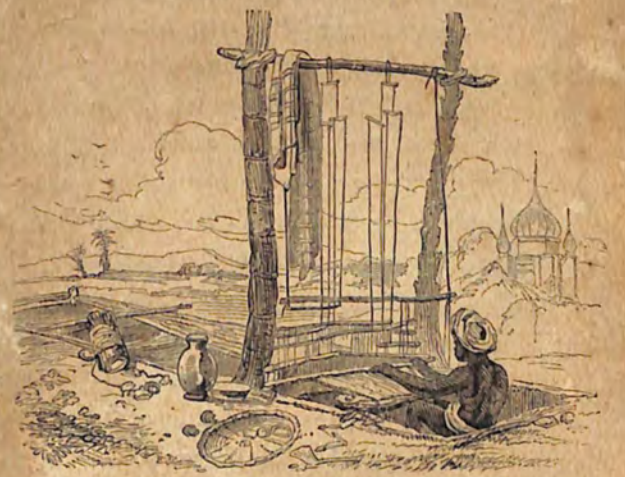
Herbaceous Cotton.

race from periods of remote antiquity. Our term "calico" bespeaks the Indian origin of that material, which originally came to us from "*Calicut.*" Notwithstanding the perfection to which our cotton spinning machinery has been brought, the muslins of India are still unrivalled. Accounts are handed down to us of the manufacture of

Indian muslins so exceedingly thin, that, if laid flat on



HINDOO COTTON-WINDING REEL.



HINDOO COTTON-SPINNING LOOM.

the ground, and allowed to become moistened with dew,

they cease to be visible. This statement, extraordinary though it may seem, is nevertheless more than probable; and yet, the Hindoo implements and machinery, by which such perfect results are accomplished, are of the simplest description.

There can be no question as to the great antiquity of cotton manufacture, both plain and coloured, in Hindostan. Herodotus, who wrote about 445 B.C., says that cotton tissues were ordinarily worn by the Hindoos,* and the testimony is confirmed, at a somewhat later period, by Nearchus.† Strabo, who died A.D. 25, mentions, on the authority of Nearchus, that the Hindoos made flowered cotton fabrics (chintzes) under the name of σινδόνας ἐνανθεῖς. An opinion has been generally prevalent that the manufacture of cotton fabrics had been prosecuted from periods equally remote in Egypt, and that the "fine linen" of Egypt was really a material of cotton. Mr. Baines has, I think, satisfactorily proved that, judging from the evidence of existing mummy-cloths, the opinion is unfounded. Having subjected many of these tissues to microscopic examination, they were found to be linen, without exception. This evidence, indeed, accords with historical testimony. Herodotus, in the book above quoted, relative to the antiquity of cotton fabrics in Hindostan, mentions not a word about the use of vegetable wool elsewhere. On the contrary, he pointedly states that Babylonian vestments

* Book iii., c. 106.

† About 327 B.C.—*Vide* Arrian's Indian History, cxvi., c. 7.

were of linen and of wool,* and that the dress of the Egyptians was only of linen, except that the priests wore a white shawl of woollen when not engaged in their ministrations.† All this evidence appears conclusive against the opinion, that cotton fabrics were known in Egypt as early as in India. Nevertheless, before the time when Pliny wrote (about the latter end of the first century), cotton fabrics must have become familiar to the Egyptians. He says, "In Upper Egypt, towards Arabia, there grows a shrub which some call "*gossypium*," others "*xylon*," from which are made the stuffs which we call xylina. It is small, and bears a fruit resembling a filbert, within which is a downy wool, which is spun into thread. There is nothing to be preferred to those stuffs for whiteness or softness. Beautiful garments are made of them for the priests of Egypt."‡

Etymologists have been perplexed in their endeavours to trace the derivation of the word *cotton*. In the Arabic the material is denominated "kôton" or "godon;" in Spanish, "al-godon," a word so evidently Arabic, that it is removed beyond the pale of dispute. The supposition is not impossible, that the Arab word "*godon*" was originally derived from the Latin or the Greek. Pliny, when describing the island of Tylos, in the Persian Gulf, mentions, on the authority of Theophrastus, amongst its remarkable productions, wool-bearing trees, having leaves exactly like those of the

* Book i., c. 195. † Book ii., c. 37, 81.

‡ Plin. Hist. Nat., lib. xix., c. 7 (Delphin ed., c. 2).

vine, but smaller: these trees, he goes on to say, bear a fruit like a gourd, but of the size of a quince, which bursting when ripe, displays a ball of downy wool, from which costly garments are made resembling linen.* Now, the Latin appellation for quince is "*cotoneum malum*," or "*cydonium*;" the Greek appellation for the same, κυδῶνιον—both derived from the word "Cydon," indicative of a city in Crete. This general resemblance of the cotton tree to the quince tree has determined, according to some etymologists, the application of the word *cotoneum* to cotton. It must be confessed, however, that the expression *cotoneum*, in the sense of *cotton*, is discoverable in no Latin records older than the eleventh century—a fact warranting the counter assumption to the one just adduced, that the Arabic word *godon* had become adapted to the Latin.

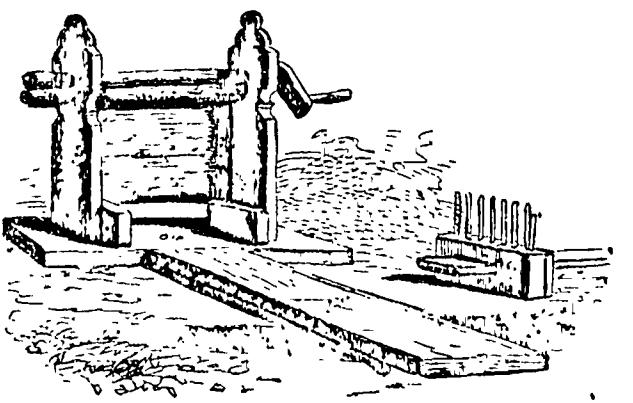
Probably the Spanish Saracens were the first who introduced cotton fabrics into Europe. They also introduced the cotton plant, which is still cultivated to this day on the littoral belt of Granada lying between the Sierra Nevada and the Mediterranean.

Although Hindostan is celebrated for its excellent native productions in cotton, yet the raw produce of that country is not well adapted to the processes of machine manufacture. The inferiority of the staple consists not so much perhaps in any natural quality, as the slovenly manner in which the plant is cultivated

* Nat. Hist., Lib. xii., c. 10.

and packed—arriving here so mixed with dirt and impurities, that its complete purification is impossible.

The cotton wool of each pod occurs in three locks or divisions, each of which envelops a seed. These seeds are rich in oil, which rapidly oozes out and damages the wool; consequently it is a point of great importance to separate the seeds before packing the cotton. This separation is accomplished by various



COTTON-DRESSING MACHINE OR MILL, IN ITS SIMPLEST FORM.

methods, according to the length of the cotton fibre to be operated upon, and some other circumstances.

The short-fibred cotton of North America is purified from its seed by a machine which may be described as a rotatory saw-mill, the revolving teeth of which pass very near to a wire cage, in which the cotton to be purified is thrown. The cotton fibres protruding through the wire inter-

stices are laid hold of by the teeth of the saw, and pulled quite through, leaving the seeds which are too large for transmission, behind. This process is very expeditious, but it is not applicable to the long-fibred varieties of cotton, for which the cotton mill is employed. In its simplest form, this instrument consists of two wooden rollers fluted longitudinally with five or six grooves, and revolving nearly in contact. The upper roller is turned by a handle, and the lower is carried along with it by a perpetual screw at the axis. The cotton is put in at one side, and drawn through by revolving rollers; but the seeds, being too large to pass through the opening, are torn off, and fall down on the opposite side from the cotton.* In America, machines on this principle, but of large dimensions, are used for purifying the long-fibred sea island cotton.

* Baines.

LECTURE I.

ON DYEING.

RARELY has chemical science been more successfully applied to practice, than in the tinctorial art—understanding by that term, not only dyeing, properly so called, but that ingenious modification of the process, calico-printing. For the most part, too, all the modern improvements in these arts have been the fruits of patient investigation and inductive reasoning: always a matter of satisfaction to the philosopher. At present, the art of dyeing, and its beautiful modification calico-printing, take advantage of some of the most refined processes of chemistry, organic and inorganic.

Before offering a slight historical sketch of the operation of dyeing, it will be necessary to state, that dyeing materials admit of a natural classification into two groups—*substantive*, and *adjective* colours; that is to say, certain colours are susceptible of imparting a *permanent* tint to materials dipped into them, without the assistance of any adjunct; such are termed *substantive* colours. Others, on the contrary,—and these constitute by far the greater number, and the more valuable dye-

stuffs,—are not thus susceptible of imparting their tint, without the assistance of a second body, to which the term "mordant" (from *mordere*) is applied, on the supposition of its serving to *bite in* the colour. Dye-stuffs belonging to this class are termed *adjective*.

Viewed with regard to their degree of permanence, adjective colours, as the rule, possess the advantage; and as the dye-stuffs known to the ancient Greeks and Romans were nearly all of the substantive class, it follows that the resulting tints must have been for the most part fugitive. To this rule, however, there were some remarkable exceptions, as we shall see by and by, more especially in relation to the Tyrian purple. If we pass beyond the historical confines of Greece and Rome, and trace the progress of dyeing through Egypt and the East, we find, so far as imperfect evidence enables us to judge, that this art was there in a much higher state of development than it ever attained in Greece and Rome.* There is reason to believe that the process of calico-printing has been followed in India from a period long anterior to any existing documents of history. It is more than probable, too, that the process of calico-printing was known to the ancient Egyptians. At any rate, Pliny † has described a pro-

* The art of dyeing was little cultivated by the ancient Greeks, slightly more by the ancient Romans, but never to the extent it was afterwards developed by artisans of the eastern empire.

† Pliny's "Nat. Hist." xxxv. § 42.

cess as being conducted in Egypt, which so nearly relates to the operation of calico-printing, that, if it be not that art (with which it is quite accordant), we know of no other to which the description corresponds. The description is as follows:—"There exists in Egypt a wonderful method of dyeing. The white cloth is stained in various places, not with dye-stuffs, but with substances which have the property of absorbing (fixing) colours. These applications are not visible upon the cloth; but when it is dipped into a hot cauldron of the dye, it is drawn out an instant after dyed. The remarkable circumstance is, that although there be only one dye in the vat, yet different colours appear upon the cloth, nor can the colour be afterwards removed."

The art of dyeing was never carried, by either Greeks or Romans, to a state of perfection so high as this; but there is reason to believe that the process so minutely described by Pliny as being followed in Egypt during his time, was derived from India—where *indigo*, one of the most valuable agents known to tinctorial art, has been prepared from time immemorial, and employed as a dye-stuff. This circumstance alone is sufficient to prove to what a high degree of excellence the tinctorial art had arrived in India. The substance indigo, as will be seen hereafter, is a body of very peculiar qualities. It cannot be used as a dye, until by some means it has been dissolved; and its solution can only be accomplished by refined chemical

processes. As a dyeing material, indigo was totally unknown to the ancient Greeks and Romans. Indeed, the substance did not become employed for this purpose in Europe until the middle of the sixteenth century. Nevertheless the Greeks and Romans possessed indigo, as we are informed by Pliny;* at least, the substance termed by this naturalist "*indicum*," and described by him as brought from India, can scarcely apply to any other. The employment of indigo as a tinctorial agent involves a greater amount of chemical knowledge than the Greeks and Romans possessed. They were content with grinding it down, and using it as a pigment.

If we are to rely on the statement of Clavigero, one of the early authors who wrote concerning the natural history of America, indigo was prepared and used by the Mexicans long before the Spaniards arrived in that country. Hernandez, moreover, describes the indigo plant as being a native of Mexico. Ferdinand Columbus, in his life of Christopher, also testifies to its American origin, stating it to be a native of Hispaniola. In opposition to the testimony of both authors, the Abbé Raynal asserts that it was transplanted from the East

* Pliny appears to have had very inaccurate ideas concerning this substance, and to have considered it as the scum or exudation of certain reeds, adhering to mud.—"Ab hoc maxima auctoritas Indico, ex India venit arundine spumæ adhærescente limo; cum teritur nigrum, at in diluendo misturam purpuræ cæruleique mirabilem reddit."—Pliny, lib. xxxv., c. 6. Dioscorides thought indigo was a stone.

Indies to America. His remark, however, can only apply, Mr. Bancroft has shown, to one of the species—the *Indigofera tinctoria* of Linnæus.* It was not until about the middle of the sixteenth century that log-wood and indigo began to be employed in Europe as dyes, and not then without considerable opposition from the cultivators of woad, who had sufficient influence to cause statutes to be passed prohibitive of indigo —a substance to which they gave the name of "food for the devil."

The most celebrated dye of antiquity is doubtless the imperial purple of Tyre,† so called from the place of its discovery, fifteen centuries before Christ. The colour, as is well known, was obtained from two genera of shell-fish—buccinum and purpura.‡ It was procured in greatest perfection by puncturing a vessel in the neck of the animal, and applying pressure—under which circumstances, two or three drops came out; but this plan being tedious, the shell-fish were occasionally pounded in a mortar, and their juices collected. As the result, however, of this latter process, the colour was of inferior quality. The colouring matter was not employed in its raw state. Being mixed with about six times its bulk of water, salted, boiled, and skimmed, it became adapted to the wants of the

* Bancroft on Permanent Colours, p. 98.

† Tyrian purple was known to the Egyptians in the time of Moses.—Exodus xxv. 4.

‡ Fabius Columna thinks that the latter were also distinguished by the name of "murex."

manufacturer. Thus prepared, there resulted a substantive purple colour, of various shades, for *wool*—which appears to have been the only textile material employed by the Tyrians as the recipient of their dyeing operation. After having been well cleansed, the wool to be dyed was immersed into, and kept in contact with the prepared liquor for the space of five hours, by the expiration of which time it had become fully charged with the dye material.*

By means of the two genera of molluscs already mentioned, and by means of certain adjuncts, such as alkaline liquors, fuci, &c., the Tyrians managed to get various shades of the celebrated purple. One of the colours was a dark violet;† but the most esteemed of any possessed the tint of coagulated blood,‡ a tint which appears to have been imparted by a double process—the wool being first steeped in the juice of the purpura, afterwards of the buccinum. Wool thus imbued with the double Tyrian dye became so costly, that, in the time of Augustus, one pound of it sold for no less than £36 sterling. Wool thus dyed was exclusively employed for manufacturing the imperial robe; many sumptuary laws were enacted in favour of it; and the penalty of death was awarded to any person who, not being an emperor, should presume to clothe himself

* Pliny's "Nat. Hist." ix., 38.

† "Nigrantis rosæ colore sublucens."—Pliny's "Nat. Hist." ix., 36.

‡ "Laus ei summa in colore sanguinis concreti, nigricans aspectu, idemque suspectu refulgens."—Pliny, "N. Hist." ix., 38.

with a robe of Tyrian purple. It would appear that the art of dyeing the Tyrian purple was studiously restricted by each successive emperor to a few families, in order that the secret might not become known. At length, in the twelfth century, owing to some unknown cause, the process became interrupted, and, during many centuries, lost. Subsequently, however, it was re-discovered in this country by Mr. Cole; (the discovery having been made during the reign of Charles II., in 1683), who obtained it from the buccinum; and by MM. Jussieu, Reaumur, and Duhamel, in France. The history of its discovery by Mr. Cole, of Bristol, is curious, as showing how important secrets often linger in remote spots, among uneducated people. Mr. Cole had received information that a poor person in Ireland supported himself by marking initials, of a delicate purple colour, on cambric handkerchiefs. He furthermore heard that the liquid employed for this purpose was obtained from a shell-fish. Further investigation into this matter proved that the Irish peasant was accustomed to employ the real Tyrian purple, as obtained from the buccinum. Mr. Cole made several experiments on this interesting substance, and, by means of it, succeeded in dyeing wool. It is related, for instance, that a pair of stockings thus dyed was forwarded to Charles II. The observations of this naturalist related merely to the *buccinum*, leaving the other genus, *purpura*, to be identified. This, however, was speedily accomplished in France.

There can be no doubt as to the identity of the fluids obtained by Mr. Cole, MM. Jussieu, Reaumur, and Duhamel, with the Tyrian purple of old. These naturalists all agree in stating the important fact, that the peculiar purple tint was not imparted until the wool had been for some time exposed to the agency of heat and sun. This precisely accords with some particulars handed down to us from the eleventh century, by an eye-witness, of the operation of imparting the Tyrian dye. The narrator is *Eudocia Macrembolitissa*, daughter of Constantine VIII. She lived in the eleventh century, while the knowledge and practice of dyeing with Tyrian purple for the use of the emperors, and at their expense, was carefully guarded as a monopoly. This curious narrative details the successive change of colours which the tissue underwent before finally assuming the permanent purple tint.*

As might be anticipated from a consideration of the low state of chemical science, or, more properly speaking, its total absence in ancient Greece and Rome, the adjective colours known to these people were few in number. The chief adjective colours known to the Greeks were various species of madder and galium—substances the use of which had long before been common in Hindostan. To these substances the

* This statement is made on the authority of Berthollet, who refers it to a collection of "Anecdota Græca," published by M. D'Anse de Villoisin. Bancroft also refers to the circumstance in his Treatise on Permanent Colours, p. 91.

Romans, amongst whom the art of dyeing had become farther developed than amongst the Greeks, added the kermes insect,—a dye-stuff rarely employed, since the discovery of America furnished a substitute in the more brilliant cochineal.

It will be seen, then, that the art of dyeing had never, amongst the classical nations of antiquity, received any high degree of development. This is no more than might naturally be expected, having regard, firstly, to the low condition of chemistry; secondly, to the low estimation in which the industrial arts were held by these people. About the fifth century, when the northern barbarians overran the western empire, nearly every trace of industrial science was obliterated in Italy. Some little, however, did remain, more particularly in Venice, where, just one thousand years after that period, the science of dyeing formed the subject of two* learned treatises, in neither of which is indigo or cochineal mentioned,—a circumstance which renders the supposition probable, that boththese important tinctorial agents were then unknown.

Having sketched the progress of dyeing in Italy and Greece, down to the prosecution of the art on scientific principles at Venice in the fifteenth and sixteenth centuries, it may be as well to take a glance at the

* "Del arte de Tintori," by *Mariegola.* The first edition appeared at Venice in 1429, the second in 1510. *Plictho* "Del arte dei Tintori," by *Giovanne Ventura Rosetti,* 1548.

state of development to which it had arrived amongst less civilised people.

The ancient Britons, as is well known, were in the habit of painting their bodies blue with "woad," the *Isatis tinctoria* of Linnæus. Whether they used the juice as a dye-material for tissues, we are unable to say, evidence on that point being absent; but the employment of the juice for any purpose is interesting, as enabling us to institute a comparison between the intelligence of our ancestors, and the Hindoos, in respect of similar tinctorial matters. The juice of woad is very nearly of the same chemical constitution with that from which indigo is derived. Yet our ancestors never accomplished more than a simple expression of the juice; whereas in India, from time immemorial, solid indigo has been prepared. Amongst the Gauls, if we are to accept the testimony of Pliny, the art of dyeing could scarcely be said to have existed. It is true these people tinged their clothes with numerous colours; but none of them were permanent, therefore the fabrics so coloured could never be washed.* "Such ancient substantive colours, however," remarks Mr. Bancroft in his Treatise on Permanent Colours, "were not always fugitive." Herodotus mentions a people,† living on the borders of the Caspian Sea, who,

* Transalpina Gallis herbis Tyrium atque conchylium tingit omnesque alios colores. Sed culpa non ablui usu. Lib. xxii., § 3.

† Book Clio. CC. iii.

by bruising the leaves of a particular tree, and mixing them with water, obtained a colour, with which they afterwards painted or stained their garments with the figures of animals, &c., which figures, he adds, water would not efface; on the contrary, they remained until the cloth was worn out, as if they had been woven therein.

The discovery of America, at the latter end of the fifteenth century, contributed greatly to the improvement of the art of dyeing, by the introduction of several important agents, amongst which may be especially mentioned, logwood, quercitron, Brazil wood, cochineal, and annatto. The opposition which the introduction of indigo first met with has already been adverted to. Logwood was not more favourably received. Its use was prohibited under a heavy penalty by a statute of Elizabeth, which enjoined the destruction of all found in the country.

The next great development of the art of dyeing did not take place until the latter end of the 18th century, and was dependent on the expansion of chemical science. To this epoch we must refer the introduction of madder, Prussian blue, chrome yellow, chrome orange, and manganese brown. The latter colour, so extensively used in common prints, was the discovery of Mr. Hartman, of Munster, about 1822. It is developed by first impregnating cloth with sulphate or chloride of manganese, and then passing it through caustic alkali. Thus treated, the white protoxide of

manganese absorbs oxygen, becoming the brown peroxide, a deep rich colour, unalterable by light or air. "The cheapness of this metallic dye, and its permanence," remarks Mr. Baines,* "have brought it into extensive use in calico-printing; but, more than all, a series of beautiful processes are founded on the proportions and combinations of manganese and chrome, in which the resources of a refined chemistry have been applied with the happiest success."

I commenced this lecture by stating, that all colours, regarded as dyeing materials, naturally arranged themselves under the two classes of "substantive" and "adjective;" that is to say, colours which attach themselves to fabrics without the aid of any second substance, and colours which require the assistance of certain intermediate bodies, generally known by the appellation of *mordants*. From this statement it must not be imagined that any given tinctorial agent is "substantive" or "adjective" for all substances indifferently. We shall find, as will be seen hereafter, the greatest difference to exist in this respect between different materials. I shall first demonstrate this proposition by means of *indigo*,—a substance which, by the way, has very peculiar chemical properties, so as to be altogether removed from the category of other colouring matters. The chemical peculiarities of indigo, however, I shall defer to another occasion, merely premising here, that the substance is capable of existing in two states—namely,

* "History of Cotton Manufacture," p. 278.

as *blue* indigo, and as *white* indigo—the former of which only is a direct tinctorial agent. Blue indigo, however, is not soluble in water; and, inasmuch as the white rapidly changes to the blue variety by combination with oxygen, this principle is commonly taken advantage of in most cases wherein it is desired to employ the material for dyeing, or calico-printing. The employment of indigo, however, to which I am now about to draw your attention, involves no such indirect chemical principle. I am about to call your attention to the dye-liquid termed "*Saxon blue*," and which is merely a solution of blue indigo in oil of vitriol—a fluid in which it dissolves readily, and yields a solution which, being diluted with water, constitutes an admirable dyeing material. This "Saxon blue" is so intensely coloured whilst in its undiluted condition, that it almost seems black. The power of its colour may be rendered apparent by mixing two or three drops with a large volume of water. I have here prepared a proper solution of this "Saxon blue," and immerse into it three skeins of different materials—one of *silk*, another of *worsted*, a third of *cotton*. These three skeins having been allowed to remain for the space of a few minutes, moved about from time to time, and squeezed for the purpose of giving access to the dyeing fluid between all the interstices, I now remove, and wash them. Observe the result. We find that the three different materials have been dyed to a very different extent. On carefully washing the cotton skein, I

find that nearly all the colour is removed,—from which result it appears that, so far as relates to the *cotton*, Saxon blue is not a substantive colour; yet indigo is one of the most common blue materials employed in the operation of calico-printing, although it cannot be used in the condition of Saxon blue. The precise method adopted for dyeing cotton by means of indigo will fall under our notice hereafter. I now remove the skeins of *silk* and of *worsted*, and carefully wash and rinse them, till the water which runs off is no longer coloured. How different is the result to that which we observe in the example of cotton. The skeins, both of worsted and of silk, are permanently dyed; thus proving that, so far as relates to *them*, Saxon blue is a *substantive* colour. Indeed, Saxon blue is the colour by which blue woollen cloth is usually dyed. It also enters as a constituent into the dye for hats.

I will now proceed to examine the comparative dyeing effect of two other colouring matters on silk, wool, and cotton. The first of these is *safflower* (petals of the *carthamus tinctorius*). Having made an aqueous decoction of this dye-stuff, I immerse into some of it three skeins as before—one of *cotton*, another of *worsted*, and a third of *silk*. In this case, again, an inequality of effect will be observable. I allow the skeins to remain a few seconds immersed, and I now remove them, rinse them in warm water, express all superabundance of coloured fluid,—and observe the

result. Of the three skeins, that of cotton has imbibed the maximum amount of colour; next in order comes the skein of silk; and, lastly, the woollen skein.

If, instead of decoction of safflower, I now take one of *cochineal*,* and repeat the experiment on the three skeins, —and a third relative order of tinctorial effect is observable. In this case the silken skein has absorbed the maximum charge of colour, and the worsted skein the minimum charge—the skein of cotton affording an intermediate result. According to the evidence, then, of the three experiments just performed, the three cases may be represented as in the appended tabular arrangement.

FOR INDIGO.	
Silk	Maximum.
Worsted	Medium.
Cotton	Minimum.
FOR SAFFLOWER.	
Cotton	Maximum.
Silk	Medium.
Worsted	Minimum.
FOR COCHINEAL.	
Silk	Maximum.
Cotton	Medium.
Worsted	Minimum.

These experiments are sufficient to demonstrate the fact that, for the three colouring matters which have been the subject of our experiment, a difference

* Cochineal is the female of an hemipterous insect denominated *coccus cacti*, from the circumstance of its feeding upon the *cactus* or *nopal* (*opuntia cochinillifera*). Each insect is about one or two lines in length.

exists in their tinctorial power as regards the three materials, *wool, cotton,* and *silk.* Nor is the difference peculiar to the colouring matters just employed. It is not a special, but a general case, applying more or less to perhaps every colouring matter which has at any time been employed by the dyer. Supposing, then, no chemical means to exist for equalising this effect of dye-stuffs—that is to say, of making them "adjective colours"—the dyer would be restricted within very circumscribed limits, and the refined operation of calico-printing could never have passed beyond a narrow sphere of development. Let us, for instance, contemplate such a case as the following:—Let us assume, as is often the case, that the problem might be enunciated, of finding a means to dye a *mixed fabric* with the uniform tint of a tinctorial liquid possessing an affinity only for one of the materials of that fabric:—supposing, for example, our mixed fabric were one of silk, wool, and cotton, and that we desired to tinge it uniformly blue by means of indigo:—it is evident, from what has already passed under our notice in a preceding experiment, that we could not effect our object by means of Saxon blue—*i. e.,* solution of indigo in oil of vitriol—because, treated with this liquid, cotton is scarcely coloured, and wool not so much as silk; hence the general effect would be mottled, dull, and unsatisfactory. Another combination differing from Saxon blue, it is evident, must be had recourse to; but, as I said

before, indigo is a colour so totally different from all others in its chemical relations, that we may advantageously postpone our chemical investigation of it until the future lecture, which is to treat of calico-printing. I will therefore pass on to a consideration of what would be the result of steeping a mixed fabric of silk, wool, and cotton, into a decoction of *safflower*.* In this case, as we have seen, the woollen fibre would be scarcely tinged, although the silken portion of the fabric would be well dyed, and the cotton portion best of the three. Or, substituting a decoction of *cochineal* for safflower, the operator would again experience a difficulty; the three materials, silk, wool, and cotton, would all be unequally dyed. These difficulties are overcome by the employment of substances termed "mordants," and to which I now purpose directing your attention.

The appellation "mordant" is applied generally to

* The safflower, or *carthamus tinctorius*, is an annual, originally from India, but now cultivated in various parts of Asia, America, and Europe. Its petals contain two colouring principles, one of which, *yellow*, easily soluble in water, masks the second, a *red* colouring agent, soluble in alkalies, from which it precipitates on the addition of an acid. The latter tinctorial principle, named *carthamine*, is a substance of considerable mercantile importance. The safflower of Persia and of Egypt has the greatest repute. Next follows that of Spain. The produce of France, Mexico, and Germany is inferior. The dye yielded by safflower enjoys but little permanence; nevertheless, its extreme beauty, and the numerous tints of which it is susceptible, determine its frequent employment.

numerous bodies which have the property of fixing colour on fibres or textile fabrics. Mordants do not belong to any natural or chemical division, nor do they operate in accordance with any one property in common to all. On the contrary, they differ in their composition, their mode of action, and their results. For instance, the function of certain mordants is limited to the fixation of a colour already existing; whereas the function of others consists not only in the fixation of a colour, but also in its alteration. I shall commence my exemplification of the nature of mordants by taking up a very well defined and remarkable class—those the action of which is due to the formation of insoluble coloured bodies, termed *lakes*. Various metallic oxides have the property of generating lakes to an extent more or less pronounced; but pre-eminent above all others in this respect are *alumina* and *oxide of tin*. I shall first direct your attention to the earth *alumina*, or *oxide of aluminum*; it derives its name from *alum*—the salt of which it constitutes an important constituent.

COMPOSITION OF ALUM.

Alumina	11
Potash	10
Sulphuric acid	34
Water	45
Crystallised alum	100

Although alum is the most convenient source for

obtaining alumina in the pure condition, and the source universally employed by the dyer, yet it may be well to remember that the earth alumina is a very widely distributed chemical principle, constituting one of the chief materials of clays and slate, and being the principal constituent of various precious stones: for instance, the sapphire, oriental ruby, and oriental topaz. It is not my intention at this time to detail the general chemical properties of alumina. We have merely to deal with it in relation to its property of combining, under certain circumstances, with organic matters, especially colours and textile fibres.

If I take a solution of alum and add to it an alkali (I shall employ ammonia), there falls, as you see, a copious white, gelatinous-looking precipitate. This is the earth alumina in combination with water; in other words, it is the *hydrate of alumina.* I will now repeat the experiment in a modified form:—instead of adding the alkaline solution to a solution of alum in pure water, I will pour it into a solution of alum in decoction of cochineal. You observe the result. Precipitation occurs as before, but the precipitate is no longer white; it is *coloured;* and the solution itself is left colourless. The alumina, in being precipitated, has evidently carried down with it the colouring matter of the cochineal, and the coloured precipitate is no longer soluble in water. This function of alumina is not exercised in this specific case alone—

that is to say, on the colouring matter of cochineal, but numerous, and in point of fact, the greater number of liquids tinged by animal or vegetable colouring matters, are alike subject to the same effect; their colouring material is precipitated in conjunction with hydrate of alumina. Thus the addition of an alkali to coloured liquids holding alum in solution, furnishes us with coloured precipitates of corresponding tints, and belonging to a group perfectly distinct and characteristic. Other metallic oxides participate with alumina in this property to a varying extent; one of them, "oxide of tin," will speedily come under notice; meantime let me observe, that all coloured precipitates obtained by this line of treatment, are usually known by the generic term of "lakes."

Let us now take cognisance of another property of alumina. It is not only susceptible of combining, as we have seen, with certain colouring matters, and forming lakes, but it possesses another property, to which I have already adverted, a property without the existence of which the dyer would be nothing benefitted by the ability to manufacture lakes. Not only is alumina prone to unite with certain colouring matters, but also with certain *organic fibres*. Thus, for example, if a piece of *cotton* be dipped into an aqueous solution of alum, and allowed to become thoroughly impregnated with the fluid, a certain portion of alumina will be removed from the alum, and will combine with the cotton fibre. The combination takes place even without the aid of an

alkali; consequently, the chemical power which determines this result must be strong. We cannot, however, demonstrate the fact of this combination so readily as in the previous experiments, simply because, alumina being white, and the cotton fibre with which it combines also being white, we cannot render the combination directly visible to the eye. Nevertheless, we have abundant evidence of this combination. In the first place, if the cotton fibre be weighed before immersion in the alum solution, then removed, accurately washed, dried, and weighed once more, an increase of weight will be manifest. Again, if the cotton fibre, thus increased in weight, be burned, and its ashes submitted to analysis, alumina will be found. Thus in the end we arrive at the demonstration, that alumina and cotton fibre have combined—equally clear with the previous case, though less immediately cognisable to our senses.

This property of alumina, to combine on the one hand with organic fibre, and on the other with colouring matter, affords to the dyer and calico-printer a new power. The result is what one might have expected, *à priori*, from consideration of the chemical functions involved:—the alumina is capable of acting an intermediate part between the dye-stuffs and the materials to be dyed, forming a bond of union between the two. In the performance of this function alumina only fixes the original colour, it does not in general much alter it; in which respect it differs from many other mordants

hereafter to be described. Thus, for instance, the oxide of tin is, like alumina, capable of forming combinations with colouring matters, and yielding lakes. It is also endowed with the property of uniting, like alumina, with certain organic matters, and thus forming a bond of union between the latter and the colour to be impressed; but it differs from alumina in the important respect of not merely uniting with the colouring matters, but altering their tint. Thus, if a portion of chloride of tin solution be poured into a decoction of cochineal, the colour of the latter grows brighter. If now an alkali be added, precipitation is effected of the colouring matter (altered as to its original colour), in combination with oxide of tin.

A *scarlet* colour resulting from the treatment of a decoction of cochineal with a chloride of tin (and tartar), is a very celebrated dye, and the history of its discovery is curious. We are informed that the Dutch chemist, Drebbel, resident at Alkmaar, had prepared a quantity of decoction of cochineal, for the purpose of filling a thermometer-tube. The preparation was effected in a tin vessel, and into this some *aqua-regia* (nitro-muriatic acid) having been spilled by accident, a rich scarlet colour was observed. Thus by mere chance was the discovery made, that oxide of tin in solution yielded, by combination with the colouring matter of cochineal, a scarlet dye. Drebbel having made the discovery, communicated it to Kuffelar, an ingenious dyer residing at Leyden. Kuffelar was

the first who carried out the discovery of Drebbel, hence the tint of scarlet produced by tin oxide and cochineal was denominated *Kuffelar's colour*. The process was not held long in secrecy; it soon became known to Van der Vecht and Gulich, who appear to have discovered the process by their own independent investigations. Van der Vecht communicated it to Giles Gobelin, who, in conjunction with his brother, Jean Gobelin, introduced it into the celebrated tapestry and carpet manufactory which still bears their name. This occurred about the year 1550. Nearly a century subsequent to this period—that is to say, in the year 1643—Kepler, who had acquired a knowledge of the process in Flanders (his native country), came over to England, and settled at Bow, where, having practised the dyeing of this colour, it went by the name of "*Bow dye*." Kepler, however, did not carry this process to so high a perfection as the brothers Gobelin, or, indeed, the dyers of Flanders; nor was the art of scarlet dyeing thoroughly known in England until one Bauer, or Brewer, having been invited to England in 1667 by Charles II., with the promise of a large salary, practised it in his own manufactory.

Alumina and oxide of tin may be both denominated lake-forming mordants. They both agree in the general character of uniting with certain colouring matters, and yielding lakes. A great number of exceedingly valuable mordants, however, possess no such effect, although they have the property not only of fixing a pigment, but of altering its tint.

Prominent amongst these are solutions of *salts of iron;* which being incorporated with the tissue to be dyed, and the latter exposed to the agency of what we may term the dye-stuff, permanent alteration of the tint is the result. In this manner tissues are dyed with *Prussian blue,* and figured patterns are impressed with the same on calicoes. There are several compounds to which the general appellation *Prussian blue* is applied, the most common of them being the result of adding a solution of prussiate of potash (ferrocyanide of potassium) to a solution of a persalt of iron. Now, this beautiful pigment is not soluble in water; and, therefore, supposing its employment as a dyeing material to be desired, some indirect process of using it must be had recourse to. The plan followed is this: the tissue to be dyed is first thoroughly imbued with the solution of the iron salt, and dried. It is now tinged of a dingy orange colour, due to the presence of peroxide of iron—*iron mould,* in point of fact;—and those who know how obstinately iron mould adheres to woven tissue, need not be informed that the attachment between the oxide of iron and the same tissue is permanent.

The dyer, however, does not want to dye his tissue of the colour of rusty iron; he wants to develop the colour of Prussian blue. This he effects by passing the fabric through a bath of prussiate of potash, which immediately undergoes its usual decomposition, and gives rise to a permanent blue, wherever the iron oxide had

been previously deposited. But we will perform an experiment illustrative of the change. I have here a skein of white silk : this I dip into a solution of *acetate of iron*, which is the salt usually employed, and remove it. The skein is now slightly altered in colour; that is to say, a certain amount of peroxide of iron has become permanently combined with its tissue. I now squeeze the skein thus treated, for the purpose of getting rid of excess of iron liquor, and dip it into a solution of ferrocyanide of potassium—*prussiate of potash*. The colour at once changes, as you observe. Instead of being brown, the skein is tinged blue, and this blue is permanent. We may wash the silk, as I do here; we may boil it; we may expose it to the agency of the air; without changing the blue colour.

I have already intimated the existence of more than one pigment to which the term *Prussian blue* is applied. In point of fact, there are at least three.* Thus, for

* They may be designated as (1) the ordinary Prussian blue, already described (*sesqui ferrocyanide of iron*); (2) *basic sesqui ferrocyanide of iron of Liebig*; and (3) Turnbull's Prussian blue (*ferridcyanide of iron*). The latter substance is generated as the result of adding *ferridcyanide of potassium* (red prussiate of potash) to a protosalt of iron.

Turnbull's Prussian blue may be also obtained by adding to a protosalt of iron a mixture of yellow prussiate of potash, chloride of soda, and hydrochloric acid. The tint of this blue is lighter and more delicate than that of ordinary Prussian blue. It is occasionally used by the calico-printer, who mixes it with perchloride of tin, and prints the mixture, which is in great measure

instance, if I take a solution of red prussiate of potash (ferridcyanide of potassium) and add it to a solution containing peroxide of iron, there is very little blueness; indeed, if the salt of iron were a pure persalt, there would be no blueness. If, however, I add it to a solution of a protosalt of iron, then we get a magnificent blue colour developed, to which the appellation "*Turnbull's Prussian blue*" has been applied. Another sort of Prussian blue may be obtained from yellow prussiate of potash (ferrocyanide of potassium) by the combined agency of certain acids and heat. Thus, for example, if a little yellow prussiate of potash be dissolved in water, a little sulphuric acid added to the solution, and heated, prussic acid, readily known by its peach-blossom odour, will become developed, and a blue-coloured pigment will remain. If tartaric be substituted for sulphuric acid, and heat subsequently applied, the fixed result is

soluble, upon Turkey red cloth, *raising* the blue colour afterwards, by passing the cloth through a solution of chloride of lime, containing an excess of lime. The chief object of that operation is indeed different; namely, to discharge the red, and produce white patterns, where tartaric acid is printed upon the cloth; but it has also the effect incidentally of precipitating the blue pigment and peroxide of tin together on the cloth, by neutralising the acid of the permuriate of tin. This blue is believed to resist the action of alkalies longer than ordinary Prussian blue. Mr. R. C. Campbell observed, that the ferridcyanide of iron may be distinguished from Prussian blue by the circumstance, that when boiled in a solution of yellow prussiate of potash, it affords red prussiate of potash, which dissolves, and a grey insoluble residue of ferrocyanide of iron, and ferrocyanide of potassium.—*Liebig.*

also blue. The composition of this latter pigment is still doubtful; but under the name of "*bleu de vapeur,*" it has been employed in the art of dyeing and calico-printing, more especially the latter. The process consists in first steeping the tissue to be dyed in a solution of prussiate of potash, afterwards in a solution of tartaric acid; and finally exposing the fabric to the action of a steam bath: under which treatment decomposition is effected, and the whole tissue becomes blue. The appellation "*bleu de vapeur*" is referable to the method employed for obtaining the result.

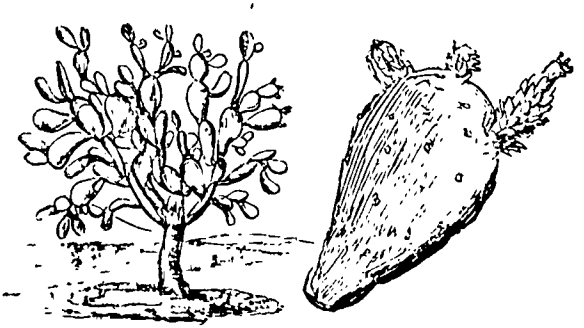
In the preceding sketch it has been my object to present you with an outline of the principles on which the art of dyeing depends. The practice of this art would be far too extensive a topic for discussion in one lecture, and, indeed, supposing unlimited time at the lecturer's disposal, he could scarcely do justice to a subject which frequently requires elaborate mechanical contrivances to give effect to the chemical principles involved. Throughout this lecture I have especially directed your attention to the art of dyeing, properly so called—namely, the art of imparting colour evenly and uniformly. The subject of *calico-printing* will come under our notice hereafter, subsequently to the discussion of *bleaching:* meantime it may be as well for me to indicate the leading principle upon which the operation of calico-printing depends, and which may be defined as the art of topical or partial dyeing with adjective colours. In the course of my operations with

various mordants, you will have remarked, no doubt, how completely dependent upon the agency of such mordant was the permanent imparting of colour. It readily follows, then, from this consideration, that were we to mordant a piece of suitable tissue, in spots or patches, and dip it whilst in this condition into the dye-material as before, the dyeing result would be no longer general, or equally diffused, but *topical*. On this principle depends a large portion of the calico-printing operation; —certain parts of the tissue being *mordanted*, whilst other portions remain untouched, the whole tissue is passed through a vat of dye-stuff, taken out, rinsed, and dried, when finally the print is rendered apparent. The whole of the calico-printing operation, however, does not depend upon the application of this principle. Occasionally we shall find that colouring matter is laid on evenly, and the tint subsequently *discharged* in patches by means of a bleaching material. Hence, before we can with full advantage enter upon the consideration of this application of science, we must discuss the theory and practice of *bleaching*.

There is yet one more important and general principle which the calico printer has recourse to for gaining his results; and it is a principle which you will readily comprehend, even at this stage of our progress. If a portion of white tissue be dipped into a vat of dye-stuff, the latter will combine, supposing it to be a substantive colour, or the tissue to have been suitably mordanted. If, however, this white tissue

be covered here and there with a thin coating of some material not affected by the liquid of the dye vat, and the whole piece of tissue be now immersed, it will evidently follow, that on such portions of the tissue as may be so covered or protected, no colour will be impressed; and on the subsequent removal of the protecting material, by mechanical or chemical means, a pattern in white will be obtained. Wax, varnishes, and a mixture of pipe-clay and size, are the principal protecting materials resorted to in such cases.

Another beautiful mode of producing the same effect is called *discharge-work*, in which white patterns are produced upon coloured grounds, by a very refined modification of bleaching by chlorine. But we shall have other opportunities of resuming these matters more in detail.



COCHINEAL PLANT—(*Opuntia Cochinillifera*).

LECTURE II.

ON THE OPERATIONS INVOLVED IN BLEACHING.

It might be thought, that in a series of lectures like the present, any description of the process of bleaching should take precedence of that of dyeing, inasmuch as in practice, there exists a necessity for the following of such routine. Certain theoretical reasons, however, exist for inducing a lecturer to consider the dyeing operation first. These reasons have reference to the theory of the action of *chlorine* in discharging colour—a function which has been already indicated in the preceding lecture, and which it will be the principal object of this lecture to explain more fully.

The greater number of textile fabrics, perhaps all, require to be *bleached* before they can be rendered fit for the operation of dyeing; and the process of bleaching is not the same in each case. It will be my present object to explain more particularly the operation, or rather series of operations, had recourse to in the bleaching of *cotton.*

From whatever species or variety of the "*gossipium,*" or cotton-yielding plant, the native material is ob-

tained, it never occurs sufficiently free from impurities, to admit of its being woven into calico, and at once submitted to the calico printer, without the preliminary operation of bleaching. Bleaching, properly so called, is not executed on the material at once. Several preparatory treatments are necessary. The first preliminary operation consists in taking advantage of fermentation as a means of removing certain vegetable matters with which the native cotton-fibre is contaminated. In addition to the vegetable matter actually decomposed by the fermentive process, another portion becomes loosened to such an extent, that it may be separated by mechanical means. For the purpose of effecting this separation, the calico is next subjected to the agency of a machine termed the *dash-mill*, the operation of which consists in moving it continuously about in contact with air and moisture, by which means the bleaching effect is promoted another stage. The course of preliminary operations is now advanced by another step: but the cotton is not yet in a condition to be subjected to the operation of bleaching, properly so called. A certain kind of resinoid matter lingers with extreme obstinacy, and until it is removed the bleaching operation will not take effect. For the purpose of accomplishing the removal in question, the goods are now subjected to the combined agency of carbonate of soda and quick-lime, a mixture which liberates soda in the caustic state; and this latter, uniting with the resinoid matter, forms a kind of saponaceous result, not difficult to be

washed away. This operation is called *bowking*. But the use of alkali necessitates a further operation : cotton fibre possesses so strong a tendency to combine with alkalies, that union, a somewhat permanent union too, results. Hence the necessity of following up the last operation by a process of steeping in a weak acid. Having been thus prepared, the cotton is next exposed to the agency of chlorine, either free, or applied in such a state of combination that it admits of being readily evolved; chlorine, in point of fact, is *the* agent by means of which the rapid modern process of bleaching is performed; and a description of the various methods of employing it will constitute the main portion of this morning's discourse.

First of all respecting the nature of chlorine. Very few members of this audience need be informed that chlorine is one of the simple or undecomposed bodies. It ordinarily exists as a gas, but by the combined agency of cold and pressure, it may be caused to assume the condition of a fluid; not, however, with such facility as to enable the fluid to be used in the arts. The usual method of generating chlorine consists in mixing together equal measures of common salt and peroxide of manganese, putting the mixture into a retort, adding sulphuric acid diluted with about an equal volume of water, and applying heat. The chlorine is evolved in the form of gas, and may be collected by means of the pneumatic trough. Chlorine has very marked chemical properties. It has a powerful odour; is a strong sup-

porter of combustion under some circumstances; and, what more immediately concerns us at this time, it is a powerful bleaching agent.

This bleaching power of chlorine may easily be demonstrated by many simple experiments. If, for instance, a solution of sulphate of indigo be diluted with water, in such a manner that a deep blue fluid results, and if now chlorine gas be transmitted through the liquid, the latter will speedily lose its tint, and become nearly devoid of colour.

Thus the bleaching agency of chlorine has been demonstrated for one case. We may easily extend the demonstration to others. Instead of a blue liquid others may be employed—such as the yellow liquid resulting from the infusion of safflower; the infusion of peach wood; and, indeed, generally of any tinctorial vegetable substance. Having demonstrated the bleaching effect of chlorine on the infusion itself, let us now try the effect of this agent on tissues already dyed. I here take a bottle containing chlorine, and moistening a piece of dyed calico, I immerse the latter into the gas. Almost immediately the bleaching operation commences; and very soon the colour will altogether fade away.

It appears, then, that chlorine is a very effectual bleaching agent; but in order that it shall manifest this quality, a certain condition has to be complied with: the chlorine must be in combination, or in contact at least, with *water*, otherwise the bleaching effect does not take place.

In our first experiment, which consisted in transmitting chlorine through an aqueous coloured solution, there was the assisting agency of water. In our last experiment, which consisted in exposing a piece of dyed woven texture to the action of chlorine, the texture was previously moistened.

We have now to consider a property of gaseous chlorine, concerned, indeed, in the preceding experiments, but not specially treated of. Chlorine is soluble in water. This is a property which, as we shall see hereafter, greatly increases its effective power as a bleaching agent. Had it not been soluble in water, then, although its bleaching energy, theoretically considered, might have been the same as we now find it, yet its practical bleaching energy would have been very different; inasmuch as the bleaching result which we have seen manifested on a coloured liquid, could only in that case, have been exercised at the points of contact between each minute bubble of chlorine and the liquid to be bleached. Chlorine being soluble, however, its bleaching energy is not limited by points of contact, but by the extent of the area of solution. The best way of demonstrating the bleaching advantages resulting from the solubility of chlorine in water will consist in employing an aqueous solution of chlorine instead of the gas itself; by proceeding thus, a fact now left in the state of inferential demonstration will be directly proved.

Chlorine gas admits of being collected over water,

as we have seen, therefore its solubility in water cannot be very great. Much depends, however, (other conditions being the same), on the circumstance, whether the water into which the chlorine is transmitted be agitated whilst in contact with the gas, or allowed to remain at rest. Much also depends on the temperature of the water; for although cold water, under agitation, rapidly absorbs chlorine, yet boiling water absorbs none of the gas; and hence, if a cold aqueous solution of chlorine be heated to boiling, all the chlorine it had previously absorbed is given off.

In order to obtain an aqueous solution of chlorine, I take a bottle containing this gas; I remove the stopper under water, and agitate the bottle. This operation being continued during a few seconds, the water rapidly ascends, and the bottle, previously full of gas, becomes now full of liquid.

Even those who are the most unacquainted with technical operations, and the various necessary circumstances which aid or impede the practical application of chemical agents, will at once comprehend the great difficulties involved in the employment of gases on the large scale, in comparison with the difficulties involved in the employment of liquids. When, in addition to these general difficulties—which, depending as they do on the physical condition of the gaseous state, apply to all gases alike—the manufacturer has to deal with a noxious gas, such as chlorine—a gas which is so exceedingly irritating to the lungs, that even here, on the small scale, where, in

spite of all my precautions, the few bubbles which have escaped produce inconvenience — when the manufacturer has to deal with a gas like *this*, his difficulties are much increased. Accordingly, the circumstance of chlorine being soluble in water, in itself affords a great addition of convenience and power. The atmosphere in which the workmen live and breathe becomes less suffocating, and the chlorine becomes more susceptible of topical application; the latter a vast advantage of itself, and one frequently turned to account in practice.

Having decided upon the advantages which would accrue to the manufacturer provided an aqueous solution of chlorine possessed a similar energy with that of the gas, let us try the effect, as a bleaching agent, of the solution we have generated.

Pouring a little of it into a glass, I also add a portion of a coloured solution, and the result is as before: the coloured solution becomes colourless—its coloured agent becomes bleached.

Great as are the advantages which for many purposes an aqueous solution of chlorine presents over the gas itself, yet, if there existed no better means of concentrating the energies and localising the action of chlorine than this, the use of the agent would never have become so general as we find it at the present time. Accordingly, very soon after the first employment of chlorine in the industrial art of bleaching, chemists turned their attention to the devising of a means whereby chlorine might be reduced to its most practically

portable form—whereby its pungent irritating smell might be overcome, and its bleaching effect rendered easy of local application.

By far the most eligible method of employing the bleaching agencies of chlorine consists in first combining it with lime, then employing the compound thus formed—a compound usually denominated "*chloride of lime*," not that it is composed of chlorine in direct binary union with lime, as the term "*chloride of lime*" would indicate. Various discrepancies of opinion exist as to the exact nature of the compound, but commercially it is still known as "*chloride of lime*," or more frequently, "*bleaching powder*."

As a preliminary to demonstrating the bleaching action of this substance, it may be as well to go through, on a small scale, the process of its manufacture. The first step consists in *slaking* lime by the addition of a little water; under this treatment the lime soon falls to powder, and much heat is evolved. If a little of this *slaked lime* be taken (it should be perfectly cold, and hence arises a difficulty in conducting an extempore manufacture like this), if a small portion be taken and projected into a jar full of chlorine, the mouth of the jar closed by means of a flat glass-plate, and the whole agitated, the chlorine will soon be found to have entirely disappeared. In the jar, for instance, now under examination, not the slightest evidence, by colour, odour, or any other quality, of chlorine remains. It has gone entirely; it has been absorbed into the slaked lime; from which it may, how-

ever, be readily evolved. To demonstrate the existence of chlorine in the new compound, it suffices to take a portion of it, and having placed it in a glass or test tube, pour over it a little dilute acid, when the chlorine becomes evolved, and may be recognised by its usual qualities. The facility with which chlorine can be evolved from this substance is most important. It forms the basis of a most ingenious application of the bleaching effect of chlorine to calico-printing already adverted to.

The force of combination existing between the chlorine and its associate in this bleaching powder is so nicely balanced, that various degrees of bleaching energy may be developed by various modes of treatment. For instance, the substance itself, without any adjunct, will bleach—as may be readily demonstrated by mixing a portion with water, and trying its effect on Saxon blue, the colour of which liquid is immediately discharged, provided the solution of chloride of lime be sufficiently strong. It is possible, however, (and this is the foundation of a very beautiful process,) it is possible so to dilute the solution of chloride of lime—so to apportion the relative amount of that substance and of water—that the bleaching effect of the mixture on a coloured fluid—*Saxon blue*, for instance—shall be almost entirely destroyed. Carefully apportioning the relative quantity of bleaching powder and of water, I now generate a fluid of this kind, to which Saxon blue, having the same amount of dilution as before, may be

added without the occurrence of any perceptible bleaching effect. If, however, into the mixed solution, a few drops of an acid, such as the sulphuric, be poured, bleaching immediately ensues, owing to the combination of the acid with lime, and the liberation of chlorine, which, thus presenting itself whilst in a *nascent* form to the colouring matter, exercises its maximum effect.

Now, suppose the following case: suppose that a fabric, dyed uniformly, had been touched in patches with any acid capable of discharging chlorine from diluted solution of chloride of lime; suppose the tissue thus treated to be dipped into the chloride of lime solution, does it not follow, from a consideration of what we have seen, that the colouring matter should be discharged in patches corresponding to the previous area of acid contact? And does it not follow, that if it be possible to employ some acid capable of exerting its action without destroying the tissue to which it might be applied, an evident means of forming a white pattern on a blue ground would result?

This, indeed, is the basis of a process commonly had recourse to in certain varieties of calico-printing.

It appears, then, that almost every theoretical condition that might be desired for rendering chlorine manageable and efficacious in the art of bleaching, is fulfilled by the combination termed *chloride of lime*, or *bleaching powder*—a material which is now prepared, on the large scale, by a modification of the process just demonstrated here: that is to say, gaseous chlorine,

being liberated from a mixture of salt, sulphuric acid, and black oxide of manganese, is caused to pass over and amongst large bulks of slaked lime, which, being continually moved about by rakes, the full absorption of chlorine is obtained. The circumstance has already been mentioned, that chlorine is altogether devoid of bleaching power except it be in the presence of water. The rationale of this requires to be explained. Chlorine, by action on water, decomposes the latter, more or less rapidly according to circumstances; giving rise to the formation of hydrochloric acid, and the liberation of oxygen. Most probably the ultimate bleaching effect is due to the *oxygen* thus liberated. The consideration of this subject naturally leads to an investigation of *bleaching by the old process;* or *meadow bleaching.*

As the result of a common operation of domestic economy, the circumstance is well known, that textile fabrics, if long exposed to the combined agency of sunlight, air, and water, are bleached. Until the discovery and application of chlorine, such was the process of bleaching followed by manufacturers; the tissues having been prepared for these atmospheric influences by previous fermentation and steeping in alkaline leys. In its ultimate result this process was effective enough; but the length of time required, and the numerous mechanical processes necessary, were serious disadvantages. Months were then consumed in an operation which is now performed in as many days; thus involving a dormancy of capital to an extent which may readily be appreciated.

On examining more narrowly the conditions under which this open-air bleaching most readily takes place, we shall find that certain concomitant relations of light, sun, air, and water are more favourable than others to the final result. For instance, the bleacher imagined that *morning dew* was the state of water most conducive to bleaching. He knew, moreover, that the rapidity with which the effect took place was in some measure dependent upon *electrical* conditions of the atmosphere. These observations long preceded the discovery to which reference has now to be made—the existence and the agency of a substance which has been called *ozone*.

The doctrine of which the phenomena of ozone furnish an instance and an exemplification, is that of "*allotropism*," as it is called—that remarkable condition which certain bodies possess of existing in two different states without any change of chemical composition: indeed, the very term "chemical composition" will be recognised as inapplicable to a simple body.

The word "allotropic," simply means *another state*. What may be the ultimate cause of that other state, philosophers cannot explain. The phenomenon is altogether mysterious—is inconsistent with one of our long-received chemical tenets, and can at present be merely received as an inexplicable fact. Phenomena now recognised as *allotropic* had long been noticed by chemists without receiving that amount of attention which their importance deserved; but as regards oxy-

gen, the capability of this element to exist in the allotropic state is altogether of late discovery, and due to the investigations of a Swiss philosopher, M. Schönbein, of Bâle.

Perhaps, before devoting our attention to the allotropic condition of oxygen, it may be well to prepare the ground by directing your notice to the assumption of this quality in another element, *sulphur*, which

being a solid, presents the allotropic phenomena more tangibly to the senses. It would be altogether unnecessary to point out the leading physical characteristics of sulphur, so familiar is this element to all. It is easily recognised by its colour—its brittleness—its inflammability—its peculiar smell when inflamed. Now sulphur is readily fusible, and the process of fusion and

subsequent cooling, in a certain manner, brings sulphur before us in an allotropic state. In this Florence flask is a little sulphur. On the application of heat, by means of a spirit-lamp, it fuses; and now, if it be poured at once into a basin of water, the fused mass consolidates into the original condition of ordinary sulphur—a yellow semi-crystalline, solid, brittle mass. If, however, instead of pouring the sulphur, immediately on fusion, into the vessel of water, the source of heat be continuously applied, a new series of phenomena will result. When the temperature of the fused mass has risen to 320° F., or thereabout, the whole mass, previously limpid and fluid, becomes thick and brown, almost like treacle in appearance; so that the flask may now be completely inverted without causing any of the fused sulphur to run out. The viscid condition has resulted during the continuous application of heat; yet it is not permanent. On pushing the temperature still higher, liquidity again ensues, although the colour of the liquid is now no longer as before. Instead of being colourless, or nearly so, it is almost black. The sulphur is in an *allotropic* condition—it has assumed *another state;* and the change may be rendered still more evident by pouring it into cold water, when the sulphur no longer cools into the yellow crystalline mass which before characterised it, but assumes a physical aspect very much resembling that of Indian rubber. It is, however, more soft and impressible than the latter, readily yielding to pressure, and receiving the lineaments of any unequal

surface which may be applied to it. Hence, sulphur, in this state, is much employed for the purpose of taking casts of medals, coins, &c. After the lapse of a certain time, the sulphur assumes its original, or normal condition; the impression becomes hard, and being lightly covered with bronze, a perfect and permanent representation of the coin, or medal, results. Nothing can be more dissimilar than the sulphur in these two states; nevertheless, chemical analysis fails to make known any difference: all the change is due to some molecular modification, to which, for want of a better name, the term "*allotropism*" is applied. It has been shown by Dr. Hannon that difference of mere physical appearance is not the only difference between normal or ordinary, and abnormal or allotropic sulphur; its medical properties are different also; not merely by an exaltation of its usual medical qualities, but by the superaddition of others which are altogether new.*

Another and a more remarkable evidence of allotropism, is afforded by *phosphorus*, a substance the properties of which, in the ordinary condition, are far more noticeable than are those of sulphur, and, consequently, the modifications resulting from allotropism are far more striking. In its *ordinary* condition, phosphorus, as we all know, is a soft straw-coloured, waxy-looking substance, having a very distinctive odour, and bursting

* On this subject, the reader may refer to a paper by Dr. Hannon, in the *Presse. Med. Belge, and Revue Med. Chir., tome* ix., *September*, 1851.

into flame on the application of a degree of heat scarcely higher than that of the human body. Another quality of ordinary phosphorus, is that of readily dissolving in bisulphuret of carbon; and since its large employment in the manufacture of matches, a remarkable physiological property of ordinary phosphorus has been painfully manifested. It produces, by absorption into the animal economy, a terrible disease of the jaw bones, leading frequently to their complete destruction, and consequently to the sufferer's death. Such are the more prominent qualities of phosphorus in its ordinary state; and they are so clearly defined, so well marked, that the changes wrought by allotropism will be very evident.

Few experimenters can have failed to observe that, on burning a piece of phosphorus in the open air, there remains a portion of a *brick-red* looking product. This brick-red deposit had long been noticed by chemists, and vaguely described; most authors considering it to be an oxide of phosphorus, the exact composition of which was not known. It remained for a chemist at Vienna, Professor Schrötter, to demonstrate, that the red substance could not be an oxide of phosphorus, inasmuch as the presence of oxygen was in no manner necessary to its production. This investigator discovered that the substance in question was generated with equal facility in an atmosphere of nitrogen; and pursuing his investigations in the channel pointed out by previous discoveries, he at length demonstrated that

the red substance in question was no less phosphorus than before; but that it was phosphorus in an *allotropic* state; having assumed a condition parallel to that of sulphur, already described. Within a certain range of conditions, the properties of phosphorus, in its allotropic state, are all changed. It has no smell, no taste; it has lost its easy inflammability, and may be carried about even in the pocket; it has a brick-red colour; it no longer dissolves in bi-sulphuret of carbon, and it is innocuous to the animal economy. It is phosphorus nevertheless; and, if heated under certain conditions, it reverts to the ordinary state.

Having thus imparted some idea of the functions of allotropism, by reference to two solid materials in which the new condition is very well marked, it is time to speak of "*ozone*," or the *allotropic* or "other" condition of *oxygen*. I believe the illustrious discoverer of this agent would not now object to my speaking thus distinctly in identifying ozone with oxygen in an allotropic state. For a considerable period there existed a doubt as relates to this point. When M. Schönbein first determined the existence of ozone, he imagined it to be a new oxide of hydrogen, but I think I shall not err in stating that he now considers it to be oxygen in an allotropic state. As we have now no longer a solid to deal with, but a gas, the allotropic variation will not be so immediately palpable to the senses. The properties of ozone, nevertheless, are equally well marked; and by means of a delicate test, first proposed by M. Schönbein, we can

readily detect the presence of ozone even when it exists in very small quantities. This test is paper imbued with a solution of iodide of potassium and starch. If a slip of paper of this kind be taken near the sea shore, moistened with water, and exposed for a few seconds to the air, when a breeze is blowing from the land, no evident change ensues. If, however, the breeze is blowing in the opposite direction—from the sea *towards* the land —then a peculiar indication becomes manifest: the paper, originally white, assumes a tinge of blue; thus proving the operation of a certain atmospheric influence, or agent, which we shall find hereafter to be ozone: a principle which may be developed artificially by various means. The simplest—the easiest plan is this:—Into a quart bottle, having a wide mouth, and containing a little water, place a small portion of phosphorus, well scraped, in such a manner as to present a clean surface, partially exposed to the air. After the lapse of a few minutes, the air thus treated will be found to have acquired the property of turning a slip of Schönbein's paper blue; in other words it will be found to contain ozone.

At first sight the suspicion might be entertained that phosphorous acid fumes were the agent here. Such is not the fact; the included air may be washed with any amount of water, still its power of turning Schönbein's paper blue will not be impaired. There are many other methods of generating ozone, which need not be gone into here; our especial object being not to detail the various processes for calling this agent into exist-

ence, but to demonstrate its remarkable *bleaching* effect. One means, however, of generating this substance must not be passed over, inasmuch as much of the ozonised oxygen existing in nature is, in all probability, referable to it—I allude to *electricity*. All electrical experimenters must have noticed the peculiar *odour* called into existence by an electric machine whilst in action. From the very dawn of electricity as a science, this odour has been taken cognisance of and described as the *electric smell*. Now the air which has been treated with phosphorus in the experiment already performed—a treatment which resulted in the formation of ozone—possesses a smell exactly similar, thus creating a possibility that the so-called electrical smell is immediately referable to ozone. This presumption is confirmed by the test-paper of Schönbein, which, if exposed to frequent electric sparks, or electric pencils emanating from a point, becomes in like manner tinged blue. The connection thus established between electricity and ozone, points to a fertile source of this most remarkable agent in nature.

Let us now proceed to examine the qualities of ozone considered as a bleaching agent. Pouring into a wide-mouthed bottle containing ozone, a portion of Saxon blue, diluted with water, see how speedily—how completely, the colour is discharged. More and still more may be added without prejudice to the result. It is no bleaching agent of small powers, but it almost vies with chlorine in this effect. A study of the history and qualities of ozone, beautifully illustrates the theory of the old pro-

cess of bleaching by exposure to atmospheric influences. We now begin to see the reasons why this operation was more successful at certain times than at others; why certain localities were especially adapted for it; and why the operation proceeded with increased rapidity after the occurrence of thunder-storms. A study of the history and properties of ozone causes all these formerly unknown facts to fall into order.

Although oxygen and, indirectly, chlorine, are the two chief bleaching agents employed in the industrial arts, they are not the only ones. *Sulphurous acid*, or the result of the combustion of sulphur in atmospheric air, or oxygen, is also a bleaching agent of considerable power. The experiment of moistening a red rose and holding it in that condition over a burning brimstone-match, when its redness disappears and the rose becomes white, is well known. This agency is illustrative of the bleaching effect of sulphurous acid. The rose petals, however, in this case are not bleached so permanently that their colour may not be restored; for if the whitened rose be immersed for an instant into dilute sulphuric acid, the original tint, somewhat heightened, returns. The bleaching effect of sulphurous acid is taken advantage of in certain manufacturing processes. By this agent straw-plaits for bonnets are bleached; also cotton-stockings, sponges, and some other materials.

Professor Schönbein has demonstrated that the bleaching effects of sulphurous acid comprehend two

distinct classes of phenomena. In one the sulphurous acid seems to unite directly with the colouring matter, giving rise to a colourless compound, from which, if the sulphurous be expelled by a stronger acid, the original colour of the material returns. In another class of bleaching effects resulting from the employment of sulphurous acid, the destruction of colour is permanent, and would seem to depend upon the agency of oxygen or ozone,* by the process had recourse to for producing the sulphurous acid.

Perhaps there is no operation in the whole range of manufactures which has so largely benefitted by the science of chemistry, and which so prominently manifests the advantages of its culture, as the operation of bleaching. Before the application of chlorine and its compounds to this purpose, the length of time necessary to perfect the operation not only necessitated the lying idle of great capital, but it was totally incompatible with that vast

* M. Schönbein finds (1) that the blue and red colouring principles of most flowers and fruits form, with sulphurous acid, colourless combinations; (2) that yellow colouring principles of flowers do not undergo a similar change by the action of this acid; (3) that indigo-blue, the red colour of the coccus, and the yellow colour of safflower, are not bleached by sulphurous acid, because this gas causes the oxygen which is present to oxidise, and subsequently to destroy these colouring matters. Hence it follows that the decolouration of organic substances may result from two modes of action, differing from each other: in the greater number of cases, it unites with the colouring principle, and forms a colourless compound; whilst in other cases it really causes its destruction.

development which the cotton manufacture was destined to acquire. Nor was this the only disadvantage. Certain localities were more favourable to the bleaching effect than others; and to these the fabric to be bleached had to be conveyed. Holland was particularly celebrated in this respect, especially the neighbourhood of Leyden; and for many years before the introduction of chlorine, the meadows of that locality were covered with fabrics sent from England to be bleached. The trouble, the loss, the inconvenience of this state of things may easily be conceived; and it is only when contemplating these impediments that we are prepared to do full justice to those who first drew attention to the bleaching properties of chlorine, and taught the proper method of applying it. Many celebrated names, both of our own country and abroad, figure honourably in this list. The celebrated Berthollet first drew attention to the chemical effect; and Watt, so immortalised as the improver of the steam-engine, was amongst the first who applied the process of bleaching by chlorine in England. Dr. Henry, of Manchester, soon entered this field of experiment, and effected several improvements in the manner of employing the agent to greatest advantage; but to Messrs. Tennant and Mackintosh we must attribute the credit of first inventing the admirable compound now known in commerce as "bleaching-powder, or chloride of lime."

LECTURE III.

ON CALICO-PRINTING.

HAVING given an outline of the chemistry of dyeing and bleaching, we have now prepared the way for understanding the rationale and the practice of a kindred art, the art of *calico-printing*, which embodies not only the various principles involved in the two former, but many others in addition. Few manufactures indeed, if any, require, for their successful cultivation, the possession of such varied and intimate acquaintance with different branches of science, as does the operation of calico-printing. In the greater number of manufacturing processes the operator has only to aim at one fixed result. The theoretical point of perfection is unvarying, and each step towards it is a permanent step in advance. Not thus in the art of calico-printing. Here, fashion has much to do with the result. A pattern, which may have been acknowledged as the perfection of one season, will have become obsolete by the next; and all the various appliances, chemical and mechanical, by which the result was obtained, will have become useless. The calico-printer,

therefore, who would successfully prosecute his art, must step beyond that beaten path of routine by which various industrial arts are circumscribed. He should not only have the perception to recognise, and the energy to bring into operation, any new fact of value which may be presented to him, bearing upon the art, but in his own person he should possess an extensive, a refined, a minute acquaintance with the numerous arts and sciences which bear upon his occupation. He should be an acute theoretical chemist, and a dextrous manipulator; he should be a good mechanician; and if, in addition to these qualities, he also possess some acquaintance with the fine arts and with the theory of colours, and even with botany and mineralogy, by which he may become cognisant of the natural history of substances from which colours are derived, all the more successfully will he cultivate his art. The qualities thus pronounced necessary to exist in one individual, in order that a successful calico-printer may result, might almost seem too numerous in extent, too varied in quality, for co-existence. Experience, however, demonstrates the reverse. There are, amongst our intelligent cotton-printers, many who answer to the description.

The art of permanently dyeing a piece of woven tissue of one uniform tint was a great point gained in the cause of ornamentation; and the appliances for effecting this are often, as we have already seen, numerous and refined. The art of applying colour *topically*, however, was a far greater advance, and involved a higher order of diffi-

culties. To effect any amount of variety, or delicacy of result, the refinements of chemistry and mechanism must be had recourse to; but the simpler outlines of the process of topical colouring have been practised from times so remote, that the first origin of the art is lost in the haze of antiquity. Many of the woven textures of ancient Egypt have been topically dyed, and with colours so persistent that chemical science has been unequal to the task of demonstrating the exact nature of the substances employed for the purpose. It would appear, however, that the Egyptian tissues of this kind are invariably linen, *not cotton*. In India, however, the operation of cotton-printing can be traced back to periods of remote antiquity, and the methods employed by that ingenious people can be identified with several of those brought into requisition at the present time by ourselves and other modern nations.

Although the appliances of the cotton-printing operation are so numerous, and the principles on which they depend are so varied, yet the final objects sought to be attained, may be reduced to two—firstly, the obtaining a desired pattern—secondly, the fixation of that pattern. Now the simplest method of impressing a pattern—the method which would at first suggest itself to a beginner—would seem to consist in the employment of carved blocks or stamps, which, being charged with the dye-stuff to be employed, should be then pressed by some convenient means upon the white texture the ornamentation of which was desired. This process was

no doubt that originally followed in Hindostan; and under the appropriate name of "*block-printing*" it has been handed down to operatives of the present day. The theory of this process is so exceedingly simple that very little description is requisite in order to render the rationale of it evident. The variety of coloured combinations, moreover, of which this variety of art admits would seem to be subjected to no limits, save those of expense involved in multiplying the blocks, and in the number of colours available to the manufacturer's use. I have before me, supplied through the kindness of a scientific calico-printer, some of these printing blocks; and now, for the purpose of rendering evident the various stages of the operation, I shall print a length of white calico in the way ordinarily followed in this operation of block-printing.

In the first place, then, it is requisite that the white calico should be spread evenly upon a flat surface, care being taken that the fibres of the material be not distorted by unequal tension. This being done, we proceed to charge the blocks in the following manner.

Before the operator is placed what we will term a *bath*—it consists of a thick mucilaginous semi-fluid mass of paste, or other body of similar physical quality; and on this bath is floated a rectangular wooden frame, supplied with an oil-skin-bottom, the upper surface of which is smeared with the colour to be employed. Upon this coloured oil-skin, the carved surface of the wooden or metal stamp is now pressed; and the subjacent semi-

fluid mass pressing up the oilskin with perfect equability, the whole of the carved surface of the block becomes equally charged. The remaining stages of the operation are almost too self-evident for description. The block being pressed, or rather *stamped*, upon the material designed to receive the topical colour, a pattern, commensurate in extent with the area of the surface of the block, results, and the operation described, being successively repeated, the whole surface of the tissue at length becomes printed. Nothing then can be more simple than the various stages of this block-printing operation; nevertheless, when carried into practice, great manual dexterity is required to perform the operation with rapidity, and make the pattern perfectly continuous and even; without, on the one hand, allowing spaces between any two impressions, and, on the other, causing any two patterns to overlap. Such, then, is an outline of the most ancient of all the cotton-printing operations. The next process to be described, and which also possesses great antiquity, is that of "*stencilling*." Like the former it seems to have been known to, and followed by the natives of Hindostan from time immemorial. The operation of stencilling is directly the reverse of that already described. The block-printing operation depends upon the transferrence of colour laid upon raised surfaces. The stencilling process depends upon the solid surface of the plate applied for preventing the acquisition of colour. Like the preceding, this process is susceptible of imparting great ornamentation, and is

applicable to certain conditions of colour which would not admit of being printed from the surface of a block.

These are the two most natural, and most obvious processes of imparting topical colour. We now approach the consideration of others—not so obvious—requiring the application of indirect philosophical principles, in which respect they differ from most of the cotton-printing operations known to the ancients. To some extent, however, one of these modern appliances was anticipated. Many of the ancient Hindoo patterns seem to have resulted from the application of substances now technically known by the name of "*resists.*" The material anciently employed for this purpose seems to have been *wax*, or some kindred body, and the rationale of its action will be evident from the following consideration. If a piece of white tissue be dipped into a dye solution, with the colouring matter of which it is capable of uniting, it will be dyed of one universal tint. If, however, certain portions of the tissue be covered with a body through which water cannot pass—such, for example, as *wax*—and now dipped, it follows that the dyeing effect will only be manifested on the spots which are not covered by the wax; and if now the wax be removed by some proper solvent, the spots thus protected will appear of the original colour of the tissue of the cloth—that is to say white; and this white may be either allowed to remain as a permanent pattern, or may be considered as a basis on which another coloured pattern is to

be impressed. Such is the theory of *resists*, and such its practice, as performed in the earlier periods of cotton-printing. At present, wax is not the substance employed as a resist, but the general principles of the operation remain unchanged.

In all the processes of cotton-printing already sketched, the colour impressed has been the result either of direct mechanical *action*, or of *protection*. Hitherto, only the simplest forms of mechanical means employed in developing this result have been described. Modifications of them, necessitated by the surprising development of this branch of industrial art, will be treated of hereafter; meantime, I shall introduce some notice of the various chemical appliances of which the intelligent calico-printer of the present day avails himself. These chemical appliances, although exceedingly numerous in themselves, may be classified under the heads of *mordants* and *discharges*. The former, it is evident, have reference to principles involved in the operation of dyeing, and under this head have been already treated of; the latter have reference to the operation of blocking, on the application of principles involved in which, they immediately depend. The statement made concerning mordants in the lecture on dyeing applies with equal force here. Mordants are of two kinds, the *fixative* and the *alterative*. A fixative mordant is merely a substance that renders a dye-stuff permanent, without affecting any change in its tint; an alterative mordant is one that not only renders a dye-stuff permanent, but

effects also a change of colour, and in certain cases develops colour where none existed before.

It will in this place be necessary to refer to certain statements made, and certain experiments performed, in the lecture on dyeing. The action of mordants was then illustrated by examples, and certain results which required more time than our lecture could afford for their complete success, were set aside in order to be examined to-day. Proceeding to make this examination, let us now pay attention to the class of bodies termed *lakes*, especially those generated by the action of alumina on colouring matters. It will be now observed that the precipitative influence of the alumina has been complete: the colouring matter originally dissolved in the fluid being now absolutely precipitated in the form of powder. That which has here taken place in a mere solution, would have taken place with equal readiness if the colouring fluid had been imbibed by a solid, and the alumina in its proper condition applied to the latter.

The mere fixative mordants, however, fill but a secondary position in the refined art of calico-printing. It is in the use of alterative mordants that the ingenuity, the skill, the many resources of the manufacturer are displayed. To those who are familiar with the numerous tints which may be developed in one and the same mineral solution by the agency of certain tests, the theory of the process of cotton-printing by mordants will become evident by anticipation. Take for instance the metal, iron;—a solution of a salt of the peroxide of

this metal yields, when treated with infusion, or tincture of gall-nuts, a black colour; when treated with solution of prussiate of potash, a blue colour; and with sulphocyanide of potassium, a red. The two former tints, and the exact method of producing them here described, are of frequent employment in the operation of calico-printing. The third, although not employed in that art, affords a pertinent illustration of the general theory of alterative mordants. We have already determined, in the course of the lecture on dyeing, that either the mordant, or the dye, or both, should be of such a nature as to ally itself permanently with the tissue to be dyed. Now, supposing iron to be the mordant, I need only appeal to a common experiment, or more properly speaking a common accident, in order to show how great is the permanence of this union. Most persons here, especially the ladies, are aware how obstinately ironmoulds linger in woven fabrics; this arises from the great force of chemical affinity between the oxide of iron and the textile fabric. We all know that a piece of linen or cotton once stained with ironmoulds may be washed indefinitely, still the red tint will not disappear—on the contrary, it rather increases in intensity by time. Now here is a handkerchief covered with ironmoulds, not covered irregularly, however, but in the form of a pattern, and of a very unpleasing colour the pattern at present appears. Immediately, however, I dip this handkerchief into a bath of prussiate of potash, combination ensues between the acid of this material and per-

oxide of iron, on every portion of the tissue with which the ironmould or oxide had been united, and a permanently blue pattern results, no less firmly attached to the tissue than was the previously existing ironmould. At first the white portions of the fabric are rather sullied by the extension of the blue dye, but this superfluity being discharged by washing, the operation of printing, as far as relates to blue and white, is complete. I mentioned before, in the course of the lecture on dyeing, that the generic term *Prussian* blue was applied to several combinations of iron oxide, and cyanogen compounds; but the chemistry of these Prussian blues is exceedingly complex, and does not concern our present investigation to enter upon. I shall not, however, leave this subject without showing a recently devised and very beautiful method of topically applying these colours. This yellow salt, prussiate of potash, or ferrocyanide of potassium, is very easily decomposed by the action of certain acids, under the influence of heat. Nitric acid readily decomposes it; so in like manner does tartaric acid; and so do many others. In order to illustrate the general principle, I add a little nitric acid to some ferrocyanide of potassium in a test-tube, and apply heat. The salt is very speedily decomposed, and a Prussian blue results. Such is a *general* exemplification of the principle; its specific application to the operation of calico-printing is as follows. The whole fabric having been first steeped in a solution of prussiate of potash and dried, a pattern is superimposed with a

mixture of tartaric acid and gum, and this pattern is also allowed to dry. A combination of two conditions is now requisite, in order that the blue pattern shall appear—namely, the conjoint agency of moisture and heat. These are supplied by means of *steam*. The fabric being hung in an air-tight chamber, and an atmosphere of steam admitted, decomposition presently ensues, and the blue pattern appears.

Hence, in consideration of the process employed in this variety of cotton-printing, the blue thus developed is termed by the French "*bleu de vapeur*."

The various colours capable of development by treating one metallic solution with various re-agents are numerous—but the calico-printer's resources are not limited by these. He produces a great variety of further tints by combinations of the originals. Thus olives of all shades may be caused to result by first dyeing a fabric with a mixture of iron mordant and alumina, and then dipping the material into an infusion of madder; and it will be furthermore evident that, by applying different mordants in different places, and in different states of concentration, another series of effects will result. A consideration of these different conditions under which mordants admit of application, leads to the classification of these bodies as simple and mixed mordants. Perhaps the most magnificent illustration of a mixed mordant is afforded by dipping a tissue, dyed with iron and alumina mixed, into a solution of peach wood. The result is red of the most brilliant tint imaginable.

Leaving now for a time the further consideration of the chemical operations of calico-printing, we may notice some further developments which the mechanical operation of pressure has undergone in order to impress the various tints with greater rapidity, and in more varied forms. A great improvement on the system of block-printing resulted from the introduction of *cylinders*, engraved with a running pattern; but the engraving by the ordinary process is expensive, and the pattern soon wears out. Hence, in forming these printing cylinders some modification of the ordinary engraving process had to be devised. This is accomplished by the following ingenious means. The pattern is first engraved in relief upon a softened cylinder of steel; this cylinder then being hardened, it is in a condition readily to transfer its device, by pressure, to the copper surface. The original process of imparting the pattern to the steel cylinder is expensive, but the expense is amply compensated in the facility with which the pattern, once produced, may be multiplied almost indefinitely. Not only by the employment of these rollers is the labour of printing in colour greatly abridged, and time economised, but several colours are enabled to be printed at one operation. By one machine, sent for display to the Great Exhibition of 1851, no less than eight colours can be printed at once, and the tissue dried and finished for consumption; and another is said to possess still greater claims, as regards the combination and variety of colours. These machines are necessarily complicated in their

parts, but the general theory of their application may be easily explained. The patterns on cotton fabrics are usually so devised as to be frequently repeated on one length, and each cylinder is complete for one pattern, which joins completely in the exact lines from which it set out, in such manner that each revolution of the cylinder gives rise to one pattern complete, and a continuation of such revolution gives a continuity of patterns. With this description the means of effecting an imprint are intelligible; the means by which the various colours are smeared upon the roller's surface exactly over the proper area, and the excess of colour removed, could scarcely be rendered evident without ocular inspection of the machine; but they are eminently ingenious.

Although it is thus possible to imprint on a fabric many colours at the same time by means of one cylinder, yet, in practice, this operation is not yet universal. A variety of colours being laid on, each by its own separate cylinder, all of which are so accurately arranged, that the white space left by every preceding cylinder is pointed by each succeeding one. A single printing-machine of this description, arranged for the simultaneous impression of four colours, driven by steam or water-power, attended by an engineer, and a boy to supply the colour-troughs, is capable of producing as much calico per hour, printed in four colours, as would require the labour of 200 men to produce in the same time by the old method of block-printing. The economy of time and labour is, of course, still more remark-

ably conspicuous in those machines which are adapted for printing a still greater number of colours simultaneously. In illustration of the avidity with which the calico-printer avails himself of scientific principles suitable to his purpose, a beautiful application of the electrotype operation may here be noticed. Occasionally, variety is imparted to the patterns on these copper cylinders by first engraving them, then throwing down a layer of copper by the electrotype operation, and impressing this surface with another pattern. In this way some beautiful results are obtained.

Having thus presented a sketch of the manner in which the calico-printer avails himself of the use of mordants—having shown how, after exhausting the effects producible by a pair of agents, a dye-stuff and a mordant, he mingles and mixes dye-stuffs and mordants in order to increase the resources of his art—having shown how the refined principles involved in dyeing have been one by one applied—I shall now leave this branch of the subject, and proceed to offer a sketch of the application of another chemical function, namely, that of bleaching, to a production of the same general result. And here, when discussing this part of our subject, the admirable qualities of chlorine, enabling it to be used in various states of intensity, will become very manifest.

Perhaps the simplest practical example of the manner in which the *discharge* operation, as it is technically called, is produced, that I can bring before you, is the process followed in the manufacture of bandanna

handkerchiefs. The term *bandanna* is applied to handkerchiefs possessing a white pattern on a coloured—usually a Turkish red *—ground. The pattern had long been a favourite in India before the manufacture was established in this country; but to us the credit is attributable of forming this white pattern in the manner I am about to describe. Suppose a handkerchief dyed of one uniform red tint, the dye material being such that chlorine will discharge it, then it follows that if a fabric of this kind be brought in contact with chlorine at certain parts, the red colour will be discharged, and a white bleached pattern will result. Nothing can be more simple than the theory of this process; nevertheless, various considerations have to be taken cognisance of in practice. Firstly, the chlorine must be reduced to such a state that it may be conveniently and efficiently

* The art of dyeing Turkey red on thread or yarn has long been practised in the Levant. Into Europe, however, its introduction is more recent. About 1795, a Frenchman, M. Papillon, introduced it into Glasgow. The art of dyeing cloth Turkey red was not discovered until 1810, M. Daniel Koechlin, of Mulhausen, having been the first to practise it. The following year, the same manufacturer effected the important discovery, that cloth died of this tint, printed with acid, and subsequently immersed in chloride of lime, was bleached. In 1814, the process was patented in this country by Mr. James Thomson, of Primrose, near Clitheroe. In 1816, he patented the discovery, combining with the acid some mordant or metallic oxide, capable, after the dye-colour was removed, of having imparted to it some other colour. Thus was the foundation laid for a long series of operations, involving the use of chromic acid and its combinations.

applied; for gaseous chlorine would be unmanageable. Secondly, provision must be made for localising the action of the bleaching agent within the exact limits of the pattern. Thirdly, provision must be made for the more rapid performance of the operation than could be accomplished by acting on one handkerchief, or one thickness of fabric at a time.

Now the first condition is fulfilled by employing chlorine in the state of aqueous solution. The second and third conditions are fulfilled by the simple process now to be described. A thick layer of superimposed tissue is subjected to severe pressure between a pair of perforated leaden plates, the perforations corresponding to the pattern which is to result. Preliminaries being thus arranged, the chlorine solution is made to percolate the whole tissue, in patches limited by the non-perforated portion of the leaden plates, whilst all absorption of the bleaching fluid beyond the prescribed limits is obviated by the mere effort of pressure. Thus each perforation in the upper leaden plate corresponds to the superior aspect, or upper section of a capillary bore, the tubular portion of which is formed by the meshes of the tissue; and in this way the colour is effectually discharged from every piece—the simultaneous bleaching of numerous layers, a condition so necessary to practical success, being effected more easily on the combined layers, than it could have been on merely one. But the powers of the beautiful principle just developed do not end here. Instead of using a mere discharge, it is competent for

the operator to mix with it some metallic body capable of receiving a determinate tint, thus giving rise to the same effective result as would have ensued if the metallic colouring body had been imprinted on a white surface. Thus the operation of discharge admits of being converted into a means of chromatic modification. A similar remark applies to resists.

The next process of discharging colour to be mentioned, also involves the employment of chlorine—not free chlorine, however, or a solution of chlorine in water, —but a solution of chloride of lime. Reverting to a previous lecture of this course,—that on the operation of dyeing,—it will probably be remembered that I drew attention to the property possessed by chlorine, in virtue of which the operator might diminish its immediate agency by dilution, to such an extent that a dyed tissue passed through a bath of this fluid diluted by admixture of water to a convenient extent of weakness, would not be bleached. It will be remembered, moreover, that in the same lecture the fact was demonstrated that the combined agency of certain acids and such dilute bleaching fluid would at once give rise to the bleaching results now under consideration.

Consider now the application of this fact to the operation of calico-printing by discharge. I have here a fabric dyed of the colour ordinarily known as Turkey red. It is easily destroyed by solution of chloride of lime, provided the solution be *above a certain strength.* If, however, the solution be diluted below a certain

degree, then bleaching does not ensue; or, rather, does not *readily* ensue—that is to say, the dyed tissue may be immersed deliberately in such fluid without prejudice to the tint. But if I take another fabric dyed with Turkey red, and impressed with a pattern by means of gum and citric acid mixed; if I dip this fabric into the same solution of chloride of lime—then the citric acid, exerting its decomposing power, liberates chlorine, and the tissue at once is topically bleached; in other words, a white pattern on a field of red is developed by the process of discharge. It only remains now to wash the fabric, in order to get rid of every lingering portion of chloride of lime, citric acid, and gum, and the operation is complete.

Although I selected this one example for illustrating the process of discharge by agency of chlorine, as applied to the operation of calico-printing, yet you must not regard it as almost a solitary case—you must not imagine the agency limited to the production of a white pattern on a field of red; on the contrary, its application is generally extended to produce white patterns on fields of any colour that may be removable by the agency of chlorine; and in this manner some of the most beautiful effects in the operation of calico-printing are produced.

Nor is the operation of pattern-discharge limited to the employment of chlorine and its combinations. I have here a fabric dyed uniformly with a mixture of indigo and chromate of lead, and, on touching it with

bichloride of tin, a discharge of colour immediately ensues; and a similar result takes place, if, instead of bichloride of tin, I employ sulphuric acid. It will easily occur to you how these principles can be brought into requisition by the calico-printer.

I promised, on a former occasion, to explain the nature of *indigo*—a substance which is removed from the category of ordinary colouring matters by its chemical peculiarities. Commercial indigo is a well-known blue material, altogether insoluble in water and alkalies. It is soluble, as we have seen, in oil of vitriol, constituting the well-known *Saxon blue*—a fluid which is eminently valued as a dye, but totally unadapted to the uses of the calico-printer. If this commercial or blue indigo be brought into contact with protosulphate of iron, protochloride of tin, sulphurous acid, or certain other de-oxidising bodies, it soon loses is colour—becoming, at the same time, soluble in alkaline lyes. Solution of this white indigo, or "indigo white," as it is called, has one necessary quality for a dye: it is soluble, and capable of penetrating the fibres of which tissues are composed; but it is devoid of another prime quality, "*colour*." Nevertheless, as the contact of de-oxidizing bodies removed the colour, so the contact of atmospheric oxygen causes the tint to be restored; and the dyer and, more especially, the calico-printer are thus furnished with a new means of employing indigo. Indigo grounds are, indeed, amongst the oldest, the most common, displays of the calico-printing art;

and, by the aid of discharges, white patterns upon a blue ground were created with facility. To print indigo-blue figures, however, on a white ground, was long a desideratum. Prolonged immersion, as in the case of the indigo ground, was impossible: the colour must be printed on; thus involving immediate contact with the atmospheric air, by which the soluble white indigo was converted into insoluble blue indigo, long before the former could penetrate into the tissue; consequently the pattern would not stand. Within late years, the difficulty has been overcome by the following most ingenious contrivance:—No sooner is the pattern impressed, than the printed tissue is passed between a pair of india-rubber lips, into a chamber filled with coal gas, through which the tissue is slowly drawn, and caused to emerge through another pair of india-rubber lips, thus affording time for the white soluble indigo to penetrate into the substance of the tissue; on exposure to air, it immediately passes into blue or insoluble indigo.

Commercial indigo occurs in small light pieces, of a violet-brown colour, and sometimes in cubical loaves. These loaves may be considered good when they assume a copper-coloured aspect on friction with any hard and smooth body; when there are no cavities found in their interior, presenting a series of brown or whitish coloured streaks; and, lastly, when they are free from fissure externally. If they are of a blue instead of a violet colour, it is a proof that they contain more or less of

a yellow matter. The presence of this matter in large proportion tends, by its mixture, to convert the blue into a green, and also neutralises the colour of the red matter of indigo. An obscure dark brown or dirty green colour indicates, in general, that the indigoes have undergone some deterioration in their preparation, or during their transport. Indigo is destitute of odour, provided it has undergone no alteration by heat and moisture. Indigoes are classified into various kinds, according to the country in which they are prepared, or according to their colour.

Bengal Indigo.—The trade in this indigo is chiefly carried on in Calcutta, and through the medium of the East India Company; its varieties are very numerous. The principal, commencing with those of the best quality, are—1. The superfine or light blue: this is in a cubical form, light and friable, soft to the touch, of a clean fracture, and giving a beautiful copper colour on being rubbed with the nail. 2. Superfine violet. 3. Superfine purple. 4. Fine violet, in colour a little less brilliant than the superfine, and rather heavier. 5. Fine purple violet. 6. Good violet, somewhat heavier than the fine violet. 7. Violet red. 8. Common violet. 9. Fine, good, and heavier than the preceding; colour bordering on a decided red. 10. Good red, of a firmer and more compact structure. 11. Fine, copper-coloured, redder, and more compact still. 12. Middling copper-coloured. 13. Ordinary, and low copper-coloured. This is of a copper-coloured blue, or red,

somewhat difficult to break. Its consistence is not so homogeneous as that of the foregoing indigoes.

Coromandel Indigo.—Those of the best quality correspond to the middling Bengal indigoes, and are met with in square masses, having an even fracture, but are more difficult to break. The inferior indigoes are heavy, of a sandy feel, having a blue colour, bordering on green or grey, or even black; often in very large squares, and covered with a light crust or rind of a greenish-grey colour. These are the most difficult to break of all the indigoes of commerce.

Madras Indigoes.—These have a grained, rough fracture, and are of a cubical figure. The superior qualities have no *rind;* in figure they somewhat resemble a hat, and are more light and friable than those of Coromandel. These indigoes, when of the best quality, have great lightness, but are not equal to the superfine blue of Bengal. The middling qualities have a very slight copper colour. The tint of the inferior qualities is a dark or muddy blue black, or even grey, and greenish.

Manilla Indigo.—The pieces of this material present the mark of the rushes upon which they have been dried. They are of a finer consistence and lighter colour than are the indigoes of Madras, but not so fine as the indigoes of Bengal. The better qualities are often in flat and elongated masses, somewhat porous, and consequently light. The middling qualities are of a violet colour, but they are inferior to the violet of Bengal.

Java Indigo occurs in flat square masses, sometimes lozenge-shaped. The superior qualities appear to the sight as fine as the blue violet or red indigoes of Bengal; but in reality they are not so.

Egyptian Indigo.—The superior qualities of this material are superfine and fine violet blues. They are light, but their structure is not very fine, and they often contain sand. The squares are rather flatter than those of Bengal.

Senegal Indigoes are of good quality, but they contain more earthy matter than any other indigoes in the trade.

American Indigo.—The indigoes of Guatemala, the Caraccas, and of Mexico, are of various kinds. The best are of a bright blue colour, remarkably light and fine. These indigoes are esteemed equal to the best Bengal. The inferior qualities are of a violet colour, but in general are more mixed than the Bengal kinds. Brazilian indigo occurs in small rectangular masses, or in irregular lumps, of a greenish-grey colour externally, and having a smooth fracture, a firm consistence, and a copper-coloured tint of variable brilliancy. Carolina indigo is met with in small square masses, having a grey exterior. Pieces of the best quality have a dull copper colour, bordering on violet or blue. The common qualities are almost always of a greenish blue; they are rarely found of a copper colour. The principal varieties of indigo in commerce are the Bengal, the Caraccas, the Guatemala, the Madras, and the Manilla.

Thus, one by one, have we passed under review the various processes, or at least many of them, which are adopted by the manufacturer in this interesting industrial art. Were it desirable, the numerous individual operations of which I have only mentioned a type, might be almost indefinitely increased; but it would be foreign to the objects of a lecture like this, to state more than general principles; nor would the task be easy. Although it is the function of a chemist to suggest, it is the province of a manufacturer to carry suggestions into practice, by working out details, and devising modifications, for the most part only to be carried into effect on the large scale. In this manner, although the general principles of calico-printing are the same, yet each operator has processes of his own—the rewards of his own industry, energy, perception, and capital.

The exclusive possession of such knowledge constitutes the manufacturer's reward; it becomes, and justly too, a secret, which the theoretical chemist should not, if he could, divulge. But, for the most part, these last technical refinements of any industrial art could not be made intelligible in the lecture-room, nor would they be of interest to the general student of chemistry.

LECTURE IV.

ON GELATINE, TANNIC, AND GALLIC ACIDS, AND THEIR APPLICATIONS.

I PURPOSE devoting this lecture to the consideration of that important animal substance "*gelatine;*" a substance which not only is an article of food, but which forms the basis of *leather;* and is furthermore applied to so many important uses, that its study is especially interesting. Gelatine is the animal substance which, from whatever source derived, furnishes jelly, or glue, according to the degree of inspissation to which its aqueous solution has been brought by the evaporation of water holding it dissolved. Gelatine is largely diffused throughout the structure of animals, not merely in tendon, cartilage, skin, and many other soft parts, but also in the bones, to which it imparts toughness, and a certain degree of elasticity; the two qualities constituting strength—binding together the particles of bone-earth, and diminishing the tendency to fracture. Gelatine constitutes the basis of so many culinary preparations, that it is very familiar to us, and numerous sources of obtaining it will at once present

themselves to the mind. The feet of calves, isinglass, hartshorn shavings, parchment cuttings, all, when boiled for a sufficient time, yield *jellies*, in consequence of the *gelatine* which they contain. Indeed, these substances are little else than gelatine. There are, in addition to those mentioned, other sources of gelatine, less frequently had recourse to, indeed, but nevertheless convenient under certain circumstances and in certain localities; ivory-dust, for instance, when boiled, yields a very excellent jelly.

As regards the chemical constitution of gelatine, it is by some regarded as a modification of protein; it abounds in nitrogen, as shown by the following table of its composition:—

	Atoms.	Equivalents.	Per cent.
Carbon . . .	13	73	50·00
Hydrogen . . .	10	10	6·41
Oxygen . . .	5	40	25·64
Nitrogen . . .	2	28	17·95
Gelatine . . .	1	156	100·00

The part which gelatine performs in nutrition, considered as an article of food, is a curious and interesting question in chemical physiology, but its discussion would be misplaced here. Gelatine is exceedingly soluble in water, as we are all aware. I have stated, moreover, that it enters largely, as a constituent, into many structures of the animal economy. It is a remarkable fact, however, that notwithstanding its solubility, this substance is never found in any healthy animal fluid.

We now arrive at the point of investigating the means of discriminating gelatine by chemical tests, and its characteristics will be found to be perfectly distinctive. It is rendered insoluble, and precipitated, when tannin or tannic acid is poured into its solution. This property constitutes the basis of the leather manufacture, as we shall discover hereafter. Tannin, or tannic acid, is the astringent principle which resides in certain vegetable bodies. Oak bark furnishes the most familiar instance, and was long exclusively used in the tanning operation. At the present time, however, many other bodies of kindred nature are employed. I shall more particularly describe tannic acid, and its derivative, gallic acid, presently.

Although the sources of gelatine for domestic purposes are numerous, yet the two principal are *isinglass*, and the *dried gelatine* now extensively sold as a substitute for the former. To the description of these substances, therefore,—their sources and the method of obtaining them, I now purpose directing your attention. Isinglass is, or ought to be, the dried swimming bladder of the sturgeon, although other parts of this, and even different species of fish, are occasionally employed. Isinglass is certainly a very convenient and a very elegant source of gelatine; but I am far from conceding to it that exclusive preference which is claimed by some. On the contrary, I believe the prepared gelatine to be a more convenient, as I know it to be a purer, source of gelatine.

It is purer because, in consequence of the process of manufacture to which it has been subjected, and which shall be presently detailed, all the extraneous matters are separated from it; whereas isinglass, being a natural substance—the operation of manufacture merely consisting in drying and cutting it into shreds—all the natural impurities of course remain, and have to be separated in the routine of domestic economy, whenever a perfectly pure and transparent jelly is required. The impurities now adverted to become at once evident when isinglass is dissolved in hot water. The solution, if allowed to stand at rest for a short period, will be found not to present a homogenous appearance, but to separate into two portions — the upper portion being transparent, whilst the lower portion is opaque. If the upper portion be decanted and evaporated, then the result is pure gelatine.

I am indebted to Messrs. Swinburne and Company for an inspection of their process of manufacturing those beautiful specimens of dried gelatine, now generally employed as a substitute for isinglass. The preparation is manufactured from skins—chiefly those of calves; which skins being for a long period exposed to the action of cold running water, all the impurities are washed away. The skins having thus been treated, and converted by solution in hot water into a jelly, the latter is poured out upon a flat surface, where it concretes, and, after having become sufficiently

dry, is cut into slices, or filaments, and then constitutes the manufactured article.

Although gelatine, as it exists in all soft animal subtances, is readily dissolved by ordinary boiling water—that is to say, water at the temperature of 212° Fahrenheit — yet, when protected by insoluble salts of lime, as we find it in bones, a higher temperature, and other methods are required to effect solution. In the routine of domestic economy, this is generally effected by means of a "*Papin's Digester*," an instrument consisting of a closed boiler, supplied with a safety valve weighted to the extent that may be desired. The effect of such an instrument is to check the evolution of steam, and, therefore, to increase the temperature to which the bones are exposed. Under this treatment the gelatine slowly dissolves, and yields a valuable nutriment; but, if the operation of boiling be prolonged beyond a certain period, the gelatine undergoes a change; its tenacity or glutinosity is affected, and its taste is rendered disagreeable.

Gelatine may also be obtained from bones, by subjecting them to the action of an acid capable of dissolving away their earthy portions. For this purpose the hydrochloric acid is that most frequently employed, being at once cheap, and giving rise to soluble compounds with the phosphate and carbonate of lime, which together constitute the bone earth. Large quantities of gelatine, in France especially, are prepared in this way, but the material is not of superior quality. The acid

effects some unknown but perceptible change on the gelatine, and, moreover, it is exceedingly difficult to remove the last traces of acid; traces which linger behind with extraordinary obstinacy.

We have seen that the skins of animals are composed almost exclusively of gelatine; we have seen that gelatine is soluble in water, and that it is precipitated from this solution by means of tannin, or tannic acid. A consideration of these circumstances introduces and illustrates the manufacture of leather, by the operation of *tanning*, as it is called. Before describing the steps of this operation, it will be well to mention the leading characteristics of tannin, or tannic acid, as well as its associate and derivative, gallic acid.

The appellation *tannin* is given to more than one substance, having the property of uniting with gelatine to form a non-putrescent result, and of blackening solutions of iron. Tannin has been divided, by some chemists, into two classes, according as it affords, with iron salts, a purplish, black, or greenish-black solution. To the former class belong oak-bark and gall-nuts, to the second the astringent matter of tea, cinchona, catechu, and the bark of pine and fir trees. It must be confessed that the distinction in question is not very precise, inasmuch as the resulting colours admit of modification, by the presence of extraneous matters. Besides the real or native tannin existing already formed in certain vegetables, there is also one called *artificial tannin*, first observed by Mr. Hatchett, and

88112

subsequently studied by Chevreul. This solution is obtained by treating certain organic bodies with strong acids, more especially with nitric acid. Artificial tannin is capable of precipitating gelatine, but it differs from real tannin in several important particulars.

According to Davy, 100 parts of each of the following substances contain the amounts respectively indicated of tannin:—

	Extract.	Tannin.
Gall nuts	37·5	27·4
Bark of oak entire	12·7	6·3
Bark of horse-chestnut entire	11·0	4·3
Bark of elm entire	—	2·7
Bark of ordinary willow	—	2.2
Inside white bark of old oak	22·5	15·0
Ditto of young oak	23·1	16·0
Ditto of horse chestnut	18·5	15·2
Inside coloured bark of the oak	10·0	4·0
Sicilian sumach	34·3	16·2
Malaga sumach	32·5	10·4
Souchong tea	32·5	10·0
Green tea	—	8·5
Bombay Catechu	—	54·3
Bengal ditto	—	48·1

The active, or pure part of tannin, is *tannic acid*, a substance which has never probably been obtained in a state of complete purity. The difficulty of obtaining it depends on its non-crystallibility, and on the rapid changes which atmospheric contact effects upon it. Of all the processes suggested or carried into execution for the preparation of tannin, that of M. Pelouze is the best. It is as follows:—A glass tube, conical at the

lower end, in which is placed a loose plug of cotton, and loosely stopped at the upper end, is about half filled with powdered galls; *washed* ether is then poured upon the powder, and the conical end of the tube thrust through a perforated cork into a flask, so as to collect the etherial solution, which gradually separates into two strata. The lower stratum is a strong aqueous solution of tannic acid; the upper is ether, holding a little tannic and gallic acid in solution. On carefully evaporating the former, *in vacuo*, over sulphuric acid, the tannic acid remains in the form of a bulky pale buff-coloured residue. Pure ether does not answer the purpose intended, the presence of a certain portion of water being essential. From 100 parts, by weight, of gall-nuts, 35 or 40 parts of tannic acid may be separated by the process described.

Gallic acid is met with in combination with the former, resulting, as it would appear, exclusively from the decomposition of tannic acid. At any rate, the quantity of gallic acid naturally existing in astringent tanning vegetables must be exceedingly slight. Gallic acid is prepared by exposing a solution of tannic acid, a strong infusion of galls for instance, to the atmosphere. Thus treated, the solution soon loses its transparency, and deposits a grey crystalline substance, almost entirely composed of gallic acid. By subsequent treatment with animal charcoal, the crystals may be decoloured, and obtained perfectly white. Gallic acid, absolutely free from the tannic, does not perceptibly affect solutions of

gelatine. It crystallises in long silky tufts, possesses a styptic astringent taste, and requires 100 parts of cold water for its solution. Its solubility in alcohol is greater, and it is but sparingly soluble in ether.

Gallic acid tinges the persalts of iron of a blue-black colour, forming the gallate of peroxide of iron; its colour disappears when its solution is heated, in consequence of the reduction of the iron to the state of protoxide, and the escape of carbonic acid.

The effect of heat on gallic acid is peculiar. If heated in a retort, at a temperature of 410° or 420°, carbonic acid is evolved, and the upper part of the retort soon becomes studded with white crystalline particles, constituting a new acid, termed by M. Deyeux, its discoverer, the "*pyrogallic.*" If, instead of the above temperature, the heat be suddenly raised to about 480°, the results are different: carbonic acid is still disengaged, but instead of a sublimation of crystalline matter, water is evolved, and the retort is ultimately found to contain a considerable amount of brilliant, dark-coloured material, which is another derivative, termed the "*metagallic acid.*" There is yet another derivative, or, at least, associated acid, to be mentioned in connection with the gallic, namely, the "*ellagic acid,*" for the discovery of which we are indebted to M. Bracannot. If a dilute infusion of gall-nuts be exposed to atmospheric contact for a long time, not only is gallic acid precipitated, but the ellagic also. From the mixed precipitate boiling water extracts the gallic acid, and the residue, on

being subsequently treated with a dilute solution of potash, yields a compound which may be decomposed by dilute hydrochloric acid, when the ellagic acid is precipitated in the form of a tawny powder, almost insoluble in water, alcohol, and ether.

These acids are compounds of carbon, hydrogen, and oxygen, in the following proportions *per cent.* :—

	C.	H.	O.
Tannic acid . . .	50·94	3·77	45·29
Gallic do.	49·41	3·53	47·06
Pyrogallic do. . . .	57·14	4·76	38·10
Metagallic do. . . .	72·72	3·04	24·24
Ellagic do. . . .	55·30	2·60	42·10

The theory of the operation of tanning is exceedingly simple, consisting merely in the combination of gelatine with tannic acid, forming tannate of gelatine, or more simply, *tanno-gelatine*; but the practical operation of tanning involves many other considerations, and requires much skill and care on the part of the workman to lead to a good result. We shall most advantageously initiate our study of this operation, by passing cursorily in review the difference between mere skin and leather; the one *gelatine*, the other *tanno-gelatine*.

Skin absorbs water, becomes gelatinous, semi-transparent, and putrescent. It is eagerly attacked by insects, and, if dissolved and the solution set aside, it speedily teems with myriads of animalculæ. It does not appear fibrous or reticulated, although animal fibres are there. They cannot be seen on account of their swollen condition, and close impaction one against the

other. *Leather,* although it absorbs water even more readily than skin, is altogether insoluble in water; it does not become semi-transparent by long immersion, it is not readily attacked by insects; and microscopic examination fails to disclose the presence of animalculæ in its infusion. Moreover, the animal fibres existing within its substance are readily evidenced to the naked eye. If torn, the edges almost present the appearance of a textile, or more correctly speaking, a felted fabric. Its colour, moreover, differs from that of skin, having assumed a tint of yellow, or brown, verging towards red, differing in its exact shade according to the variety of tanning material which has been employed. Oak-bark, the most ancient tanning agent known, and the one which is still most commonly employed, imparts the deepest tint, and sumach the lightest; hence the latter substance is now extensively employed in the manufacture of certain varieties of leather, to which a deep tint would be a disadvantage. It is not within the province of this lecture to take cognisance of all the technical expressions which enter into the tanner's vocabulary. Thus he has many conventional designations for indicating skins of different kinds. He does not call them skins universally, but speaks of them as skins, hides, pelts, &c. The chemical principles of the tanning art would gain little by our employment of these terms. I shall therefore use the term skin generally to include and designate every variety; simply dividing them into the thick and the thin, according as they are intended

to form upper leathers or soles. In France, the terms soft and hard are used instead, it being an object to make thick or sole leather as hard as possible; whereas, on the contrary, softness is indispensably necessary to constitute an excellent upper leather.

The commencement of the tanner's operation varies according to the nature of the skin with which he has to deal. Some skins are fresh—that is to say, they have been recently stripped from the animal; others, on the contrary, may have been brought from a considerable distance, and are either dry, or preserved with common salt. The simplest case is that involving the use of fresh or green skins—consequently it is to such that my first explanations will apply. Before the tanning operation, properly so called, can be applied, it is generally necessary to remove the hair, although, for some purposes, skins are tanned with their hair on. Depilation is accomplished either by steeping the skins in a solution of some chemical agent, or by promoting incipient decomposition, or, lastly, by the agency of steam; this latter plan being had recourse to in France more frequently than elsewhere. Lime is the chemical agent usually employed for the purpose of depilation; it is partly dissolved in, and partly diffused through, water. This substance is cheap, and, so far as mere removal of the hair is concerned, perfectly efficacious; but its employment is attended with certain disadvantages, to be specified more particularly hereafter. Instead of lime, an

alkaline solution has been sometimes employed, especially soda, and it has been attended with great advantage. There, indeed, seems only one objection to its universal adoption for this purpose,—namely, the objection of expense. A third chemical depilatory agent is sulphuret of arsenic, or *orpiment*, which also forms, in combination with lime, the basis of a *depilatory cosmetic* (a very dangerous one) for removing hair from the human skin. Lime, however, is the chief agent employed in tanning establishments as a depilatory, and its disadvantage is this:—a portion enters the substance of the leather, and there forms carbonate of lime or chalk, which is insoluble, and, therefore, exceedingly difficult to remove. Not only does this lingering carbonate of lime tend to harden the leather by its immediate presence, but, if not expelled before the tan-solution is applied, it forms tannate of lime with the latter, and its incorporation with the leather is rendered still more perfect. The expulsion of lime is chiefly effected, and the hair removed, by means of scraping, and pressure. The skin being doubled over a vertical wooden stand, is scraped with a kind of blunt two-handled knife. In this way the hair readily separates, and the absorbed lime is partially expelled. A still further portion of lime, however, is disposed of, by the subsequent operation of "*raising*," now to be described. The raising process has for its object the imparting of a porosity to the skins before steeping them in the tan-solution, thus facilitating

the entrance of the tanning principle. It consists in steeping the skin during a certain period, which varies with circumstances, in a weak acid—such as the acetic, lactic, hydrochloric, or sulphuric. In England the latter is most frequently employed; but, if theoretical indications are to be relied on, it is not the best, inasmuch as the combination of sulphuric acid with lime gives rise to gypsum, or plaster of Paris, —a compound of inferior solubility—whereas all the other acids spoken of form remarkably soluble compounds with lime. Although acetic acid (vinegar) and lactic acid have been specified as agents employed in the raising operation, yet it must not be imagined they are added to the raising vat in this state. On the contrary, both are the indirect results of decomposition effected by the manufacturer. Sometimes he procures his acid bath by fermenting spent tan—that is to say, tan from which all the available astringent matter has been removed: in this case the result is chiefly acetic acid. This process is the one most commonly employed in France. Occasionally the acid bath resulting from the fermentation of bran, barley-meal, rice, flour, &c., is employed, in which case the result is a mixture of acetic and lactic acids. When hydrochloric or sulphuric acids, however, are employed, they are added directly to the bath, and are not, like the preceding, the results of indirect agencies.

By the operation of raising, the skins are rendered swollen and tumid, their structure is expanded, and

little channels are formed for the entrance of the astringent principle. It is now time to describe the method by which this principle is applied.

Oak-bark, I have already remarked, is the tanning agent most anciently employed, and that which still continues to be used most generally, and in greatest quantity. Every species of the genus *Quercus*, however, contains, more or less developed, the tanning principle, diffused through numerous parts of the structure of the vegetable. In all the species and varieties of oak which usually fall within our observation, the tanning principle is chiefly concentrated in the bark. In the *Quercus ægilops*, however, its concentration is greatest in the large acorn cups of that species, which, when dried, constitute the *Valonia* of commerce. In England, the species from which we derive most of our indigenous tanning bark are the *Quercus robur*, and *Quercus pedunculata*. In France, the prevalent species are the *Quercus glomerata* and the *Quercus coccifera*—the latter especially in the central parts of France. Of these two species, the bark of the *Quercus glomerata* is most esteemed. Every portion of the same oak does not yield bark of equal excellence for the same tree. The maximum development of tannic acid occurs in the underwood of trees, from eighteen to thirty years old. In England and America there is a prejudice in favour of the bark of older trees, but it is only a prejudice; the opinion is not justified by facts. As regards the season most proper for stripping the bark, there can be no question that it is the spring.

Not only is practice confirmatory of this, but many years ago Sir H. Davy proved that the ratio of tanning principle in bark from similar portions of the same tree, and stripped respectively in spring and autumn, was as 6.04 to 4.38. Good bark should be very pale externally, and tend to yellow in the centre, and should be rough and dry on the woody side. Bark is prepared by the tanner for his use by comminuting it in a mill.

Having thus disposed of the most common tanning agent, it remains now to present a general outline of the others, which, although of comparatively recent introduction, are very extensively employed, and which are preferable to the former for many purposes. The material known in commerce as *sumach*, is a semipulverulent body, composed of the ground leaves, peduncles, and young branches of various species and varieties of the botanical genus *rhus*, the product of the *rhus coriaria* being most esteemed. That generally preferred by tanners comes from Sicily, but the plant is an object of culture elsewhere; and many other regions besides Sicily contribute to the commercial supply. Of the Sicilian sumach, different qualities, each presenting its own specific advantages in the production of certain kinds of leather, are furnished by specific localities. Thus, for example, the sumach of Alcamo is more particularly adapted to the manufacture of the kind of leather known as *Morocco*. Sumach also grows in Italy, Spain, and Portugal, and two kinds, termed respectively "*fauvis*" and "*redon*," or "*redoul*," are cultivated in France, the first of these being

most esteemed in consequence of its near resemblance to the Sicilian product. Its cultivation is mainly confined to the department of Var, whereas the growth of *redon* or *redoul* is almost exclusively restricted to Languedoc. The great advantage of sumach over oak-bark consists in the less amount of colouration which it imparts to the leather—a consideration of great importance in the manufacture of ornamental leathers, which have subsequently to be dyed. Moreover, sumach does not impart so great an amount of hardness to leather as does ordinary oak-bark.

Catechu, now so extensively employed in the manufacture of leather as a source of tannic acid, is the dark inspissated juice of many dissimilar botanical genera. Some of its varieties are known in commerce under the names of *Cutch*, and *Terra japonica;* it is chiefly brought from India. *Valonia* I have already mentioned to be the enlarged acorn cup of a species of oak—the *Quercus ægilops*. This substance is imported from the Levant.

Whatever the material employed in the tanning operation may be, the general scheme of its employment is the same. A solution or infusion being obtained, the skins to be tanned are exposed to the continuous agency of the same, and frequently moved about in order that every part of the surface may be equally exposed in turn to the tanning effect. The time necessary to elapse before the completion of that effect, necessarily varies according to the strength of the infusion, the thickness

of the skin, the perfection of the raising process, and many other circumstances, which the practical tanner is alone competent to take cognisance of. Hence, as conducted in the old, and still general plan, the manufacture of leather is a very slow process, occupying many months, and even, under certain circumstances, years. The commercial, or rather financial, objections to this great expenditure of time will be evident on consideration. It became a great object to shorten the process by scientific expedients, and accordingly several variations—I scarcely know whether they can be called improvements—have been at different periods introduced. Some of these I shall mention more particularly by and by; meantime I will proceed to give an outline of the different stages of the tanning operation which have not already come under our notice.

The oak-bark, being ground into small fragments by a mill, is stratified between successive layers of skins in pits. Water is then poured on, and the whole is allowed to stand at rest until the solution has been exhausted of its tanning principle. The process of stratification is then repeated, until the conversion of the skin into leather is complete; which result may be determined by cutting a portion of the skin from time to time, and examining the condition of the central substance. The section should present an uniform nutmeg-brown colour; a white contrast streak denotes imperfect tanning. When all the gelatine has combined with its full complement of tannic acid, the

tanning operation may be said to be finished. The imparting of suppleness and flexibility to the hides, so necessary before they can be applied to the numerous uses of leather, rather belongs to the currier than the tanner. Nevertheless, in many establishments, especially in France, the skins under process of tanning, are rubbed, compressed, or beaten from time to time, in order to render them supple by expression of extraneous matter. Almost every tanner employs his own modification of the stratifying process which I have mentioned, but the general object sought to be attained is in all cases similar, being the conversion of every portion of the skins operated upon, into tannate of gelatine. Considerable difference of opinion exists as to the degree of moisture under which the stratification of broken bark and skins should be conducted. As a general rule, it may be stated that the French use considerably less water than ourselves.

If the principles on which the operation of tanning depends be attentively considered, they would seem to involve the difficulty of not being able to bring the tanning fluid in contact with the central portion of the skin. In practice this difficulty is experienced. Tanners well know, that if the external portion of a skin be at once brought into contact with astringent solution above a certain degree of concentration, the further internal absorption of the fluid is checked, and the central substance of a thick skin is subject to remain untanned. Hence many devices, some of them very ingenious, have been

had recourse to by different inventors for facilitating the penetration of the tanning fluid. Some of these I shall now proceed to describe.

One inventor, Mr. Spilsbury, thought of the ingenious plan of causing a rectangular water-tight vessel to be made, the sides being formed of the skins to be tanned. To this rectangular frame a long vertical tube being attached, the astringent liquid was poured in from a considerable elevation, thus bringing the force of hydrostatic pressure into operation, by which means a power almost without limit might be applied. It was thought that the force thus generated would be competent to drive the tanning fluid quite through the thickness of the skin, and form good leather by a rapid process. The idea was ingenious, and the complete transfusion of tanning fluid was accomplished, but *good leather* did not result. Experience proved that the concentrated tanning fluid not only forced its way through the leather, but washed out a portion of tanno-gelatine, which, exuding externally, necessarily diminished the substance, and consequently the value, of the leather; in other words, tanno-gelatine was found to be partially soluble in tannic acid.

A modification of this process consisted in sewing the skin to be tanned into the form of a bag, filling the latter with a tanning solution, and suspending the bag in a warm atmosphere, by means of which external evaporation was promoted, and continuous percolation determined. This process, also ingenious, has not been

attended with the anticipated result of yielding a first-class leather. Other inventors have endeavoured to facilitate the act of imbibition by placing the skins to be tanned in a vessel containing the tanning menstruum, and from which the air might be exhausted by the agency of pumping. Others, again, have based their endeavours on the principle of squeezing the skins from time to time, so that the exhausted liquid within their pores might be expelled, and repeating the operation of immersion, thus continuously supplying fresh tanning material to the gelatine. Of this character is the process of Mr. Herapath, who begins by forming a series of skins into an endless band, one portion of which is continuously compressed by two cylinders, whilst another portion, compressed by this operation, is slowly drawn through a vessel containing the tanning liquid.

Notwithstanding the reasoning brought to bear in the performance of these new operations, a very general opinion exists, that the resulting leather is inferior to that produced by the old operation of tanning.

From this rapid summary of the principles and practice of the leather manufacture, it will be seen that chemistry and mechanism have been applied to less purpose here than in almost every other industrial art; and, without disparagement to the inventors who have devoted their talents, and capital, and energy to the object of effecting improvements in tanning, it may be said that a process of leather manufacture which shall effectually supersede the process of slow stratification, has yet to be devised.

INTRODUCTION TO LECTURE V.

ON SUGAR.

SUGAR AND THE SUGAR-CANE—THEIR HISTORY AND NATURAL HISTORY.

SUGAR, which now occupies such an important and such a peculiar position in European commerce—a substance which can scarcely be denominated one of life's necessaries, seeing that people long managed to do without it, but which, nevertheless is something more than a mere luxury, was amongst the last imported of all oriental products. Its general introduction into Europe as an article of domestic use is attributable to two causes—the Crusades, and the Saracen conquest of Spain.

The introduction of the sugar-cane into Western Asia seems to have been a modern affair. Neither sugar nor the sugar-cane is mentioned in the early records of Christians, Phœnicians, or Jews; neither is it mentioned by early Mohammedan writers—a circumstance which seems only explicable on the hypothesis that the cane

and its product were both unknown in the regions with which these people were familiar.

Amongst the writings of the poets and the historians of ancient Greece and Rome, we occasionally find passages having reference possibly, but by no means certainly, to the sugar-cane and sugar; which latter appears to have been known under the denomination of "*Indian salt*"—a term expressive, most probably, of sugar-candy, the form of crystallised sugar which most likely preceded all others. So little did the ancient Greeks and Romans know respecting the natural history of this "*Indian salt,*" that they believed it to be a concretion in the hollow of a reed.

Amongst the equivocal references to sugar and the sugar-cane by European writers of antiquity, the first which merits attention is that of Theophrastus* (B.C. 321), who, in more than one place, seems vaguely to refer to sugar and the sugar-cane. In his chapter on honey he states as follows:—

"The generation of honey is threefold: the first is from flowers, or other things in which there is sweetness; the second is from the air, which, when there are dews, is concocted by the heat of the sun, and falls, particularly in harvest time; the third sort is from canes or reeds."

Theophrastus, in another part of his writings,† mentions a sort of reed or cane growing in marshy localities

* De Causis Plant, ed Heinsii, 1613—p. 475.

† De Causis Plant, ed Heinsii, 1613—lib. vi., c. 16.

in Egypt, and possessing sweet roots. By some commentators this passage has been understood to refer to the sugar-cane, but the assumption appears scarcely borne out by the description. Neither is the sugar-cane an aquatic plant; nor are its roots so sweet as its stem. Moreover, if the sugar-cane had really existed in Egypt in the time of Theophrastus, assuredly we should have had more precise accounts of it than are to be found in the preceding obscure passages. In the history of India, by Strabo, written in the 19th year of the Christian era, it is said, that Nearchus, the Admiral of Alexander the Great, about 300 years before Christ, not only saw the sugar-cane in India, but was aware that a substance resembling honey (sugar) could be extracted from it. Assuming this statement to be correct, it is difficult to account for the imperfect knowledge of sugar and the sugar-cane entertained by Roman authors during the next three centuries. Seneca and Lucan, who lived in the time of Nero (A. D. 62), adverted to sugar and the sugar-cane in language so ambiguous, that we are left in doubt whether another plant than the sugar-cane, and another substance than sugar, might not have been intended. Seneca, in his 84th Epistle, has the following passage:—"Aiunt inveniri apud Indos, mel in harundinarum foliis, quod aut ros illius cœli aut ipsius harundinis humor dulcis et pignior gignat. In nostris quoque herbis, vim eandam sed minus manifestam et notabilem, poni quam prosequatur et contrahat animal huic rei genitum."

Lucan,* treating of the Indians near the Ganges, writes :—

"Quique bibunt tenera dulces ab arundine succos."

Pliny is the next classical author of repute who adverted to the sugar-cane. This was about the year 78. Between this period and the latter end of the dark ages, very little testimony is forthcoming relative to the plant or its product.

It is impossible to reconcile these vague accounts with the existence of the sugar-cane in Western Asia at the time they were written; and great weight attaches to the opinion, that, until the 13th century, when a regular trade sprung up between Western Asia and Europe, on the one part, and Eastern Asia on the other, the sugar-cane was scarcely known, and sugar was not produced in regions west of Bengal—the chief *locale* of the cane being China and Siam.

In the thirteenth century the commerce of India was opened; and about this time the sugar-cane first became planted in Arabia Felix—whence, following the track of the Saracen conquerors, it gradually extended into Egypt, skirted the north of Africa, and passed over into Spain.

Valencia seems to have been the part of Spain where the cane was first cultivated. The coast of Andalusia followed next: and here, in this almost tropical district (as to its temperature and productions), the cane is still cultivated with success. Here, in this fertile region,

* Book iii., verse 237.

about seventy miles long, and perhaps, on an average, three wide, large tracts of sugar-cane may still be seen, mingling with date-palms, cotton shrubs, and indigo; all introduced by the Moors.

By the end of the fourteenth century sugar had become almost a necessary of life to the Mussulman. Large manufactories of sugar now existed throughout Arabia, Egypt, and several other parts of Africa. The manufacture in these regions still extended until long after the discovery of America, when they gradually declined. England now carries on a large trade in refined sugar with the Barbary nations and Turkey. They prefer refined sugar, and cannot make it themselves. Strictly speaking, good Mussulmans ought not to eat it, because blood is employed in its manufacture. The scientific Turks, further advanced in civilisation than their fellows, do not seem to care about this. The Barbary nations are more correct; they require a proof—which is supplied to them in the form of an Arabic guarantee that no blood *has* been employed. This guarantee is furnished by our export refiners, and of course it removes all scruples.

The sugar manufacture in Western Asia and Northern Africa has now become unimportant; but there are many authorities extant, particularly the published travels of Giovanni Lioni, to prove that it had risen to great importance in the sixteenth century.

Long before this period, however, large manufactories of sugar from the sugar-cane existed in Europe, not

only in Spain by the Mohammedans, but also in Sicily, where it is recorded by Lafitan that William II., king of Sicily, gave to the monks of St. Bennett a mill for grinding sugar-cane. About this time also the cane was attempted to be grown in Provence; but the climate was too cold, or too uncertain, and the attempt failed.

In 1420, Madeira was discovered by Don Henry, regent of Portugal. He introduced the cane from Sicily, and it flourished well. Into the Canary Isles it was also introduced about this time. Madeira and the Canary Islands, in point of fact, soon became the great foci of sugar manufacture, to which Europe mainly looked for her supply, until the discovery of America. The Portuguese seemed especially anxious to encourage the growth of sugar: no sooner was the island of St. Thomas discovered, than the sugar-cane was there introduced. How it flourished may be inferred from the fact, that, in the year 1520, this colony had more than sixty sugar manufactories. Amongst the possessions of Spanish America, St. Domingo was the first to which the culture of sugar-cane was introduced, by one Pierre D'Etienne. A Catalonian, however, named Michel Ballestro, was the first who expressed cane-juice; and Gonzales de Velosa the first who converted cane-juice into sugar.

Having thus traced the history of the sugar-cane through the Saracens, the Spanish, and Portuguese, up to the beginning of the sixteenth century—having

traced it into the Canary Islands, Madeira, and America, —it will not be a little extraordinary to find, that, until the year 1520, doubts continued to be entertained at Venice as to the exact nature of the sugar-cane. Nothing can more strikingly illustrate the isolation in which nations maintained themselves in these times. These doubts were finally cleared up by the Venetian traveller Marco Polo, who, having penetrated into China, brought away with him a specimen of the real sugar-cane. Had he gone to Andalusia, he might have obtained a specimen of the cane with less trouble; but possibly doubts existed whether the cane of the western Saracens, and the cane which supplied oriental sugar, were the same. Although Marco Polo was the first to bring away from China a specimen of the cane, the names of many other oriental travellers about this period deserve honourable mention. Thus, for instance, Vasco de Gama, in 1497; Barthèma, in 1506; Pedro Alvarez Cabral, in 1520; Odoardo Barbero, in 1515; and Pigafelta, in 1519.

Already, in the beginning of the sixteenth century, America was infringing on the monopoly long enjoyed by Venice, in the supply of sugar. Venice, however, now began to enjoy another monopoly of a kindred nature—the monopoly of *sugar refining*, first discovered there towards the latter end of the fifteenth century.* Hence *loaves of sugar* were first known under the appellation in Commerce of "Pains de Venise." The

* Anderson's "History of Commerce."

first account we have of sugar-refiners in England is in the year 1659.*

Having traced the history of sugar, as resulting from the cane, up to the year 1659, when sugar was first refined in England, it may be well to advert to the unaccountable prejudice with which sugar was long regarded in England, even by several medical writers. The line of demonstration taken was curious enough,—the pungent volatile matters evolved during the destructive distillation of sugar being constrained into a testimony against the innocence of the substance yielding them. Thus Mr. Ray concludes his chapter on the Arundo saccharifera with the following censure:—"Saccharum salem acidum et maxime corrosivum continere, ex distillatione patet." The corrosive acid emanations here adverted to are, for the most part, a mixture of acetic and formic acids. I need scarcely remark, that neither of them exists in sugar: both are products, not educts. As reasonable would it be to condemn animal food because prussic acid can be evolved from it, as to condemn sugar because of its yielding formic and acetic acid on distillation. Dr. Willis wrote still more unfavourably in disparagement of sugar. Not content with the general aspersion directed against the acidity of its products, he accuses it roundly of contributing to the existence of scurvy, whereas modern experience demonstrates it to

* Anderson's "History of Commerce," vol. i., pp. 82, 246 331, 334; vol. ii., pp. 72, 105.

possess a quality the very reverse of this. "Saccharo condita," remarks he, "ut plurimùm imbuta in tantum vitupero, ut illius inventione ac usu immodico scorbuti in nupero hoc seculo immani augmento plurimùm contribuisse existimem. Enimverò concretum istud sale satis acri et corrosivo cum sulphure tamen delinito, constat prout ex analysi ejus spagiricè facta liquidò patet. Quippe saccharum per se distillatum, exhibet liquorem Aquâ Stigiâ vix inferiorem: Quod si ipsum in vesica plurimâ aquâ fontanâ perfusim distillaveris quamvis sal fixus non adeò ascendit, prodibit tamen liquor instar aquæ vitæ acerrimæ virens ac summè pungitivus. Cum itaque saccharum quibusvis ferè Alimentis mixtum ita copiosè à nobis assumitur, quam verisimile est ob ejus usu quotidiana, Sanguinem et Humores Salsos et Acres proindeque scorbuticos reddi."

Happily for the interests of sugar, physicians then, as now, were not unanimous. Whilst some violently abused it, others became its powerful advocates; amongst the latter figures prominently, and, it may be said, creditably, Dr. Slare. He went to work like a true enthusiast: not content with asserting the innocence of sugar, he elevated it almost into the rank of a panacea; not content with eating sugar abundantly, he smeared his skin with syrup, to the great *comfort* of the same, as he informs us; and he used powdered sugar for snuff, which, we are told, "did comfort his fauces, a quality which tobacco-snuff did not possess."

This celebrated advocate of sugar deserves credit for

the industrious collation of facts he has handed down to us in support of his position—facts not only drawn from the restricted circle of his own profession, but also from collateral sources. The following testimony, embodying an important statement in gastronomic zoology, is of this kind.

"I have known," says he, "a farmer near London feed his roasting or sucking pigs with white sugar in their milk, which made them sell for three half-crowns, and sometimes ten shillings a piece; and I was told by the farmer's landlady who had tried them, that they did far exceed the flesh of the common sort."

But perhaps the most telling case in favour of the good qualities of sugar, was that furnished by Dr. Slare's own maternal grandfather, Mr. Malory, of Shelton, in Bedfordshire. Everybody is aware of the common prejudice, that sugar destroys the teeth. Now Mr. Malory, who remained a great sugar eater all his life, shed his teeth *in favour of a new set* when he was nearly a centenarian! "He lived," remarks the great advocate of sugar, in a letter written in the year 1714, "an active, but sober and temperate life. He loved the diversions of hunting, a gun, and a hawk, which he kept himself; he was very regular in his method of eating and drinking; he made three meals a day, but did only eat flesh at dinner; he drank every morning near a pint of good soft ale; he then walked in his orchard so many turns as made a mile; he did the same in the even of his old age; he obliged me to walk fifteen miles with him

after he was fourscore, which he did without being weary. He seldom drank wine, but when he did, it was canary. He never drank between meals; his eyesight was so good, that he could take up a pin from the ground when he was between eighty and ninety. I have seen him kill a single bird with his gun. His stomach never failed him to the last, nor did he remember that he was troubled with the headache. In his eighty-second year he was observed to be very strong and cheerful, his hair to change somewhat dark; in that year some of his old teeth came out, and were found to be pushed out by young ones, which continued to do so until he had a new set of young teeth quite round.

"He lived easy, and free from pains or any sickness, to his hundredth year, and in that year died of an apoplexy. He delighted in all manner of divertments. He used in the morning to spread honey upon his bread and butter some part of the year—at other times to strew sugar over his bread and butter; he loved to have all his sauces made very sweet, especially with his mutton, hashed or boiled, or any other sort of meat that would bear sauces, he ordered them to be so sweet, that to others they tasted luscious.

"The good effect it had upon this old gentleman, my grandfather, together with the pleasant relish I received early in my youth, by dieting with him, made me always a lover of sugar, which I have for some years past used very plentifully, especially in my wine, and also in my ale on various occasions. I have made use of dried sugar in

powder to cleanse my teeth—and, by rubbing it into my gums, to cure them when sore and swelled; but this happened seldom, unless I had neglected the use of sugar for many months. My teeth are at present 28, the usual complement of most persons; are all of them sound and well fixed in their places: these never gave me the trouble of the toothache.

"I have also used sugar as a snuff many times with pleasure (according to the receipt above named); but all other sorts of snuffs I cannot endure, because they dry up the natural moisture, which makes me uneasy, but this affects two of my senses kindly, both smell and taste; does also lubricate the throat, and carry down through the windpipe to the lungs such healing particles as are very differing from the stimulating and corrosive dust of tobacco.

"If any one would be so curious as to inquire more particularly into the state of my health, and demand of me, as a living evidence, to give a faithful account of sugar by my own experience, and how it affected me. I shall then bring in a third case, whereas I intended to represent only two. I do declare that I cannot charge sugar with one ail or injury that it ever brought upon me: that I was for several winters troubled with a pituitous or phlegmatic cough for three or four months, due to the thick London air; that I made much use of sugar, and sometimes of honey, which did me good, and enabled me to pass the winters more easily; that the country air immediately relieved me, and in a short time

cured my cough. I am, God be praised, far from any disease, have no symptoms of scurvy or consumption, and, though over sixty-seven, yet few will allow of it by my countenance or activity that I present that age, notwithstanding my having indulged myself in such quantities of sugar. I have lived to bury above fourscore fellows of the College of Physicians that were my seniors since my first admission, and a vast number that were my juniors; many of this number were bitter enemies to that most delicious and curious preparation, fine sugar.

"I write without spectacles, and can read a small print; can walk ten or fifteen miles with ease, and can ride thirty or forty miles a day, if need require it. I may justly attribute a great deal of the healthful constitution which I now enjoy, to the nourishing and balsamic virtue of sugar. Yet I must not exclude the great benefit of the most excellent Bath waters, which have also lately contributed considerably since in removing symptoms of an incipient gout.

"Finished at Epsom, Dec. 31, 1714."

I shall dispose of our enthusiastic and amusing advocate for the use of sugar by one more quotation. It embodies a precept of enduring truth—sugar having the tendency of contributing to *embonpoint.* As regards the amelioration of temper which the worthy doctor so confidently proclaims to be the result of sugar eating, farther experience is required.

"Out of respect to the fair sex," our author goes on to say, "especially those that love their beauty, or

fine proportions, as well, if not better, than their lives, I shall suggest one caveat, or caution, to those that are inclining to be too fat—namely, that sugar being so very high a nourisher, may dispose them to be fatter than they desire to be, who are afraid of their fine shapes; but then it makes them amends by supplying a very wholesome and goodly countenance, and sweetens peevish and cross humours, where they unhappily prevail."

NATURAL HISTORY AND BOTANY OF THE SUGAR-CANE.

The sugar-cane (*saccharum officinarum*) is a vegetable belonging to the natural order, *graminaceæ*. There are many species and varieties. The height of the sugar-cane is about seven feet on the average; in tropical countries, more; in temperate regions, less. It is in the stem, not the leaves, that sugar is found, more especially in the lower portion of the stem; hence it becomes an object to cut the canes as low as possible. The upper parts of the stem are so devoid of sugar, that they are cut off before the cane is sent to the mill.

Of the sugar-mill there are many varieties. Primarily, they admit of classification into the mortar-shaped, and the cylindrical; secondarily, into vertical and horizontal cylindrical. The mortar-shaped mill has been employed from time immemorial, by the Hindoos and other eastern people—never by Europeans.

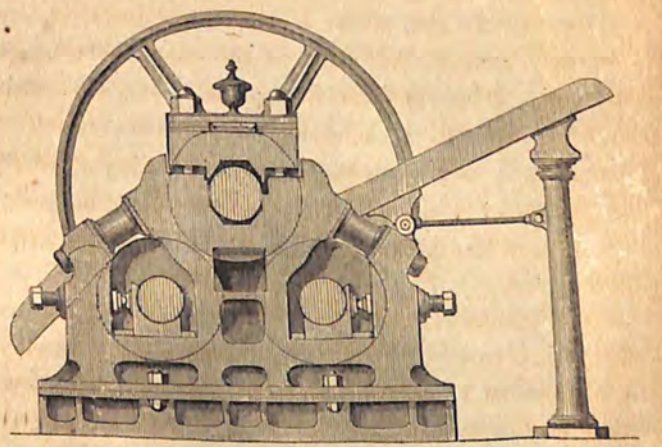
This mill consists of a mortar, beam, lever, pestle, and regulator.

The *mortar* is a tree about ten feet long and fourteen inches diameter. It is sunk in the earth, so as to leave about two feet above ground. Its upper extremity is hollowed into a conical or funnel-shaped cavity, terminating in a hollow cylinder below, in communication with the spout which conveys the juice into an earthen pot. The *beam* is about sixteen feet long and six inches diameter. It is made of a large tree, naturally divided into two arms. The forked portion of the beam is trimmed so as to admit the mortar, around which each arm of the beam revolves without touching. The extremity of the fork is left quite open, in order that the beam may be changed without any difficulty. The bullock-driver sits on the undivided end, to which the cattle are yoked by a rope from his end of the beam, and they are kept in the circular tread by another rope, which passes from the yoke to the forked end of the beam. A basket is placed upon the forks, to hold the cuttings of the cane; the man who feeds the mill, sitting between this basket and the mortar. He takes care to place the pieces of cane sloping down the cavity of the mortar, just at the time that the pestle comes round, removing those which have been squeezed immediately that the pestle has gone by. The *lever* is a piece of timber nearly as long as the beam. The thickest end, which is also the lowest is connected with the undivided end of the beam by means of a regulator. The *pestle* is a strong cylindrical piece of timber, cut to a point at each end. The upper end

is a smooth cone, the lower end a pyramid of twelve to fifteen sides, at the lower point of which is a short cylinder. As the pestle is placed obliquely, it rubs strongly against the sides of the mortar during its rotation. The *regulator* is a square piece of timber, passing through the undivided end of the beam, to which it is secured at its lower end. It is pierced by several holes, a pin being inserted through the lowest, to prevent the falling of the regulator when the strain is removed.

Of cylindrical mills, those on the horizontal construction are considered best; but, unfortunately, the very conditions of cylindrical pressure are unfavourable to the total expression of cane-juice. However accurately adjusted the cylinders may be to each other, the maximum pressure must be necessarily restricted to a mere mathematical line, and no sooner does the cane pass this, than, expanding by virtue of its elastic and spongy texture, it rapidly absorbs a portion of cane-juice. Hence arises a great loss in practice. Mr. Bessemer has devised an ingenious machine by which juice is expressed from the cane, by pressure of two flat surfaces, on the principle of a hammer on an anvil. I have never seen this machine, but have heard it well spoken of. Some manufacturers employ the hydrostatic press as supplementary to the mill. This is particularly the case in Spain, where I have seen it employed with great advantage: from twelve to fourteen per cent. of juice on the whole cane being extracted after well-ap-

plied pressure of a horizontal mill, of good construction, and in perfect order.



SUGAR MILL.

OTHER SOURCES OF CANE SUGAR IN ADDITION TO THE CANE.

Although the sugar-cane long furnished the exclusive supply of sugar, it has ceased to do so for many years. In North America the sugar maple (*acer saccharinum*) yields a considerable amount. In India the juice of various species of palm, especially the date palm, has long been an important source of sugar; and in Europe the beet root (*betula alba*) competes with the richer saccharine juices of the tropics.

Of these three sources, the sugar maple is of least importance, although the sap of this species, flowing readily from holes made in the trunk, being rich in

sugar, and occurring in regions rather cold than temperate, fermentation is not likely to set in, and the extraction of sugar is easy.

Far more important, in a commercial sense, is the date palm as a source of saccharine juice; it is quite as rich in sugar as the juice of the cane itself, and, when obtained, far more pure, being quite free from the shreds of vegetable fibre, chlorophylle, and other foreign matters due to the mechanical action of the sugar-mill. Accordingly, the date palm is, and long has been, an important source of sugar in the East Indies. Certain botanists have expressed their opinion that the palm tribe is destined, at some future time, to supersede the cane as a source of sugar; and, judging from the quantity of juice yielded by each tree, and the richness of the juice in sugar, the anticipation would not seem at first unfounded. The important fact, however, remains to be recognised, that the palm tree is not like the cane, adapted to the conditions of dense plantations, and the concentrated efforts of machinery. When it is considered that each tree requires to be punctured separately, and its juices separately collected, some idea may be formed of the number of hands required. The utilisation of this source of sugar is eminently adapted to the condition of a country densely populated with small landed proprietors, and this is the characteristic of India at the present day.

The operation of extracting sugar from date juice is thus conducted at the present time. The

small proprietor, owner of the palms, first begins by puncturing their spathes, and collecting the exuding juice. This juice he boils down into a black non-crystalline material, to which the term of *jaggery* is applied. This jaggery is subsequently re-dissolved, mixed with lime, and various nostrums, re-evaporated, potted, and allowed to drain. The solid, ill-crystallised, dark-coloured result of this operation, is termed *khaur*, which in its turn is frequently exposed by the natives to a prolonged and very wasteful claying operation, by means of which most of the dark-coloured syrup is removed, and a dull, mealy, imperfectly crystalline result remains, known in commerce as *white Bengal*. Within the last ten years, however, this final native claying operation has gone into partial desuetude, in favour of refineries under European management, from which result the finely crystallised products of Dacca, Dobah, and other manufactories of less note.

BEET-ROOT AS A SOURCE OF SUGAR.

It is to the Prussian chemist Margraff, in 1747, that the world owes the first indication of crystallisable sugar in beet-root. Forty years later, Achard of Berlin, having devoted his attention to the same subject, operated upon a larger scale, and showed the possibility of succeeding. Nevertheless, the sugar of beet-root remained for a long time an object of mere curiosity, continuing to be sold at the price of eight to ten francs the kilogramme, and

its identity with cane-sugar was even doubted. A prejudice existed that its power of sweetening was less than that of cane-sugar—a prejudice which at this time is not quite dispelled. At length there occurred a crisis in the history of cane-sugar. Soon after the continental blockade was established by Napoleon, the price of foreign sugar rose to eight or ten francs the kilogramme, and Napoleon, desirous of obviating as much as possible the evil consequences of this measure, lent great encouragement to the manufacture of sugar from beet-root, by offering a premium, and originating an imperial establishment for the manufacture of beet-root sugar at Rambouillet. Very soon, under the able supervision of M. Chaptal, the success of the manufacture was such, that beet-root sugar was sold at less price than the foreign article; but on the cessation of the continental system, the manufacture of sugar from beet-root declined. Nevertheless, the chemical processes for extracting it becoming simplified, and the import duties on exotic sugar becoming increased, the manufacture of beet-root sugar revived, and is now prosecuted remuneratively in France, Belgium, and Germany.

In France, in the year 1825, the annual consumption of sugar was 50,000,000 kilogrammes, in 1842 it had risen to 80,000,000 kilogrammes, or at the rate of five pounds for each inhabitant. In England, the consumption in 1842 was about twenty pounds for each inhabitant.

Nowhere, perhaps, is the beet-root sugar manufac-

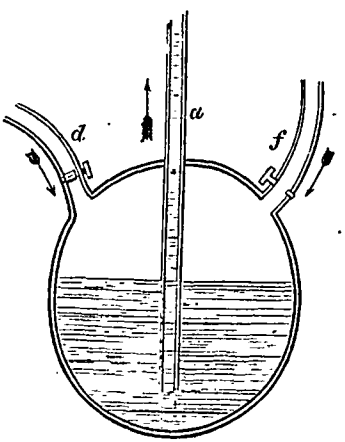
ture prosecuted on so large a scale, or with more success, than in Belgium. I have gone through various establishments in that industrious little country, but have seen nothing to compare with the scientific excellence of the process followed by Mr. Van Goethem, at Lembecq, near Brussels. The following is an outline of the process employed by that gentleman.

The beet-roots, when brought from the field, have first to be cleaned, which is accomplished by putting them into a large cylinder of iron bar-work; a sort of gigantic squirrel cage; which being caused to rotate in a vessel of water, soon effects the cleansing of the roots. The roots are next rasped into pulp, which is also accomplished by means of machinery, and the rasped product is exposed to pressure. This is accomplished at two operations, the first serving to extrude such portions of the juice as are loosely combined with the tissue; the second effecting an almost complete desiccation, hydrostatic pressure being employed for that purpose.

The juice having been separated from the vegetable tissue, requires to be freed with all possible expedition from the numerous and varied impurities it contains. The most bulky of these impurities is vegetable albumen; but the most difficult to separate entirely is a peculiar odorous matter, to which no specific name has been applied. Amongst the numerous processes which have been suggested for the defecation or first purification

of beet-root juice, lime is the most general, and perhaps the most advantageous. *

In the establishment of M. Van Goethem, the treatment of the juice after expression is as follows. The operations already described, namely, washing, rasping, and pressing, have necessarily been performed on the ground floor of the establishment. The conduct of subsequent operations requires that the



MONTE-JUS.

juice should be raised to the upper story of the manufactory. This is accomplished by means of an instru-

* My own process of defecation, by means of subacetate of lead, I never considered applicable to beet-root juice, except after the primary employment of lime. The disadvantages attendant upon the use of subacetate of lead would be the large amount required, and the large amount of acetate of lime ultimately produced by the addition of chalk to neutralise acetic acid.

ment termed a *monte-jus*—an instrument frequently employed for this purpose in France and Belgium, and which might with great advantage be extended to our own West India Colonies. The *monte-jus* acts on the principle of raising a column of fluid by direct pressure of steam.

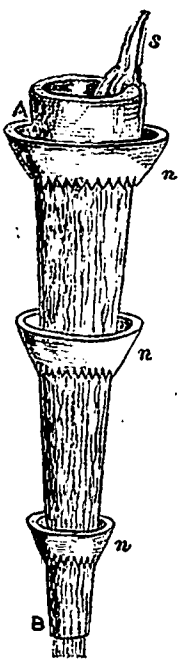
It is subject to various modifications of form, but the following diagram explains the general principles of its construction. The ovoid vessel is intended to contain the liquid to be raised.

This liquid is assumed to have flowed in through the tube *f*, which is seen to be furnished with a stop-cock to be shut when necessary; *a* is the pipe up which the liquid is intended, by means of the *monte-jus*, to be raised; and *d* a steam pipe also furnished with a stop-cock.

Now, supposing the ovoid vessel here represented to contain liquid, and the tube *a* to extend to its lower part, it follows that by admitting a jet of steam at *d*, the liquid will be raised in *a* proportionate to the elastic force of steam. Supposing the liquid to be raised is water, and the pressure of steam 15 pounds on the square inch, then the water will be forced up the tube *a* in a column 33 feet in perpendicular height; but as the juice of beet-root possesses a higher specific gravity than water, the extent of vertical elevation would be proportionately less. However, sugar refineries generally employ high-pressure steam for the engine, that is to say, steam of 30, 40, or 50 pounds pressure to the inch,

by means of which an upward pressure of juice may be obtained, sufficient for the necessities of most establishments.

Having been lifted by means of a *monte-jus* to an upper floor, the juice is now transferred to a copper heater bedded in a steam jacket, by which the juice may acquire a temperature something less than that of its boiling point. Cream of lime is now added, and the scum which arises carefully removed by skimming; finally, the juice thus defecated, is filtered, either through cloth bags or spent animal charcoal,—*i. e.*, animal charcoal which, having been used for decolouration, is exhausted as regards its chemical effect, but which is still a good agent for effecting mechanical filtration.



CONE DE LEMBECQ.

The next process consists in evaporating the juice, which, in the establishment of M. Van Goethem, is thus ingeniously effected by a conical copper chimney ordinarily known as the "*Cone de Lembecq.*"

The sides of this vessel are made hollow for the purpose of constituting a steam jacket; and now it will be perceived that such a cone is possessed of two evaporative surfaces—one internal (which is hidden), another external. The mode of action of such a cone

will be readily understood. Suppose a current of juice, *s*, to be split into two portions—one leaking down externally, the other internally—both will be subjected to an equal amount of heat. The evaporative power of the internal surface will, however, be the greater of the two, on account of an upward current of heated air, determined by the hollow of the cone acting like a chimney. The use of the stops, *n*, *n*, *n*, is to regulate the flow of the descending liquid, and distribute it over the copper surface in a thin sheet. By this ingenious contrivance the juice is concentrated to about 26° or 27° of Beaumé's saccharometer, about the density at which animal charcoal exercises its maximum effect. Accordingly the next operation is that of *charcoal filtration*, properly so called; *i. e.*, filtration not for the purpose of removing vegetable fragments, coagulated albumen, &c., but for the purpose of rendering the juice white, or at all events tending to whiteness.

By means of this process, if a sufficient amount of animal charcoal, well burned and of good quality, be employed, the filtrate may be rendered totally colourless; but the peculiar odour of beet-root lingers most obstinately, and, indeed, can only be got rid of in the end by crystallisation, draining, and liquoring—the ultimate result of which operations is to convey all this odorous matter into the treacle.

Practically we may consider the subsequent treatment of beet-root juice, in all its remaining stages, as involving no necessary departures from the ordinary

practice of refineries; that is to say, the liquor might be subjected to vacuum-pan evaporation, and the result formed into loaves as usual. Such, however, is not the plan adopted by M. Van Goethem. This gentleman avoids the use of the vacuum-pan at any stage of the operation, relying altogether upon the evaporative powers of the copper cones already described.

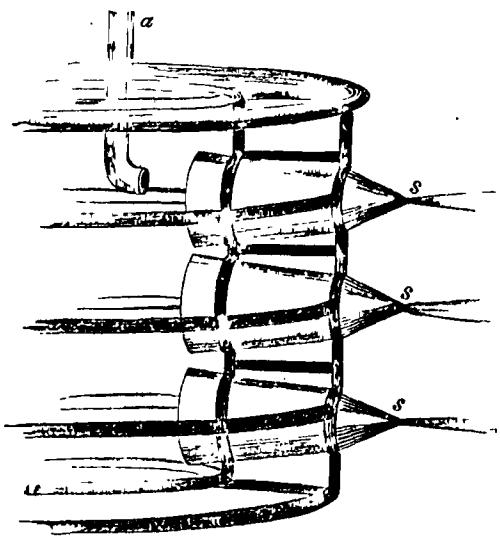
Were the object proposed to convert a limited amount of liquor into sugar, in the minimum period, from first commencing the operation, undoubtedly the vacuum-pan would be superior to any other vessel; but in a continuous series of operations extending over a long period of time, then the question of superiority between the vacuum-pan and the process adopted at Lembecq becomes doubtful. Personally I am inclined to give preference to the latter. If, however, the system of cone evaporation be adopted, it must be in connection with the system of ultimate spontaneous evaporation, in which, indeed, consists the fundamental peculiarity of the process of M. Van Goethem. The system of spontaneous evaporation is conducted as follows:—Having passed the charcoal-filtered liquor over the surfaces of the evaporating cones, until the degree of concentration recognisable by practice has been attained, it is now put aside in a tank, and mixed with a certain amount of crystalline sugar, obtained from another stage of the process. This crystalline sugar serves as nuclei of larger crystals, which, after having thoroughly formed, are removed, either by dipping, or decanting the non-

crystallised liquid above them. This is a general indication of the system pursued, which involves the spontaneous formation of crystals. The factory contains many hundreds of these crystallising tanks, each of which corresponds with a certain definite period of the operation, and certain definite crystallising fluids. All details of the operation are confined to the manufacturer; but the general principle on which the operation is based is sufficiently evident: it has reference to the generation of crystalline particles around previously existing nuclei.

This beautiful system—so accordant with chemical theory, and so efficient in practice—could scarcely be carried into effect without the collateral employment of centrifugal machines (*turbines*) for the purpose of freeing the crystals from adherent non-crystalline matter. Accordingly these machines are extensively used at Lembecq, and in all other manufactories where the system of M. Van Goethem has been adopted.* Some of these turbines are merely employed to dry the semi-crystalline magma put into them; however, the crystalline products, which are subjected to centrifugal action towards the end of the operation, are not only dried, but liquored also. Finally, crystallised sugar having been at length obtained *almost* pure, it is mixed in a copper heater, with a sufficient amount of pure sugar dissolved in water to convert it into the necessary consistency for being poured into moulds. These moulds might be

* A drawing and description of the simple turbine will be found in the lecture itself, at page 203.

treated in the ordinary manner of refineries; but in the establishment which I have been describing, they are again subjected to the process of solution. The loaf turbine may be popularly compared to a steam-boat paddle-wheel, horizontally poised on a vertical axis, the paddles taken out, and rings substituted in their place. These rings are intended to give horizontal support to the



LOAF TURBINE.

loaf moulds, as indicated by the diagram,—but not fully depicted, in order to avoid confusion of lines. Three tiers of loaves are usually arranged in one centrifugal wheel, which being set rapidly in motion, the contained syrup rapidly percolates away, as represented by *s, s, s;* and, after the lapse of a certain time, which

practice readily determines, the operation of liquoring is performed by liberating a jet of liquor from the pipe *a*.

A consideration of the mechanical principles involved in the construction of this elegant machine, proves, that although the loaves are horizontally laid, nevertheless the liquor falling upon their bases can only escape by one of two channels. It must either percolate through the loaf, or must overflow the brim of the cone. Accordingly, the quantity of liquor used in one operation is so apportioned by previous experience, that the amount which flows over the bases of moulds in the top row shall fill the second, and the overflow from the second shall about suffice, without any remainder, to fill the third.

This is a very ingenious and a very efficient machine; but I do not imagine it could be applied to the draining of loaves heavier than sixteen pounds, without involving such an amount of danger and difficulty as would prove insuperable. Even now, the machines, as used in the drainage of sixteen-pound loaves, generate so great an amount of centrifugal force when rapidly revolving, that the consequences of an accident to one of them would be frightful; nor, unfortunately, is this a matter of speculation merely. About three years since, one of them broke in pieces whilst revolving: its fragments were hurled in all directions, and no fewer than eight men were killed.*

* At Valenciennes.

LECTURE V.

—✦—

ON SUGAR AND ITS MANUFACTURE.

THE subject of my lecture to-day is one of great interest and importance, under whatever aspect we may view it. Whether we regard the social questions involved in the colonial extraction of sugar, the enormous quantities of the material produced, the still more enormous quantities lost, or the numerous elaborated contrivances which have been proposed, or carried into execution, for refining the raw material—the sugar manufacture is in every point of view deserving our attention. No alimentary substance (except those absolutely necessary to the support of life) has ever grown into such extensive demand, has involved interests of such great importance, or determined the investment of such gigantic capital, as sugar. Among imported alimentary bodies, sugar, regarded as an article of commerce, is second only to corn. Its use is daily extending, and it is difficult to recognise any limit to that extension, other than the limit of supply. Those of us who merely contemplate the subject of sugar under the aspects suggested by the breakfast or tea-table, will hardly be

prepared to learn how enormous are the quantities which enter into commerce. On this point I may cite the authority of certain articles which recently appeared in the *Morning Chronicle*, on the subject of the sugar specimens in the Great Exhibition. The articles in question were written, as it appears, by Dr. Scoffern, who has since embodied them in the form of a pamphlet, of which I have now before me a copy. Adopting Dr. Scoffern's statistics of sugar, which I believe to be correct, it appears that about one million tons of sugar *per annum* enter into the current of European commerce, without taking into consideration the large quantities produced in China, the Malay archipelago, and Siam, of which no certain statistics exist, but which may be assumed to amount to another million tons. Now, with regard to the monetary value of this sugar, Dr. Scoffern estimates it as equal to an average of £15 per ton at the place of extraction. Hence the total value of two million tons of raw sugar, at the place of preparation, will be no less than thirty millions of pounds sterling *per annum*.

Passing on from a consideration of the annual amount of sugar *produced* from the cane, and other sources, to the amount *lost* in the process of extraction, we find here a subject of painful contemplation. The relation of the amount lost to that actually produced, is enormous. There can be no question about this matter. It is not asserted by the advocates of any one process or the other. All persons conversant with sugar are

unanimous in the statement, that at the lowest estimate, for every weighed amount of sugar obtained, an equal amount is lost, owing to imperfect methods of conducting the operation. Dr. Scoffern has adduced evidence to prove that the loss is nearer two-thirds than one-half. I am not prepared to disprove this assertion—it may be true; but that one-half is lost as the *minimum*, has been conceded, I believe, by all chemists who have turned their attention to the processes of native sugar extraction. So great a loss is altogether without parallel in any other chemical art.

As these lectures are intended to be strictly practical, and are intended to afford an outline of the processes of sugar extraction and manufacture, both in the colonies and in refineries, I shall omit all historical narratives concerning the first introduction of sugar into Europe; nor shall I occupy your time with discussions concerning the knowledge of this substance possessed by the ancients. These are interesting topics, about which much has already been written, and much still remains to be written: to the practical man, however, their interest is not equal to the interest involved in the *sugar manufacture*, to which, therefore, I shall now address myself without further preface.

And first of all, what is sugar? What are we to understand by this term? Why, chemists are still undecided as to its exact limitation. We shall be tolerably correct, however, if we define sugar to be any sweet substance of organic origin. Regarded in the sense of this

definition, we may speak of the sweet material of manna, of liquorice, of fruits, and of milk, as being sugars. But of all these, only *two* will merit our careful notice—the sugar of grapes, and of fruit generally, otherwise called *grape sugar*, and *cane sugar*. Of these, the latter is immeasurably the more important,—to such an extent, indeed, that we might, in a practical lecture on sugar, omit all notice of the former, were it not for the circumstance that cane sugar is subject, by the operation of many causes, hereafter to be detailed, to become converted into grape sugar.

By the appellation *sugar of the cane*, we are not to understand a sweet body which is necessarily extracted from the sugar-cane as its only source, but all sugars which are chemically identical with the same. Thus, for instance, in North America, the *maple* (*acer saccharinum*) is a source of sugar; in regions where the *date palm* grows, this tree is a very common source; indeed, very much of the sugar supplied by the East Indies has been derived from the latter origin. The *beet-root*, too, both red and white, is a source of sugar not less interesting, as regards the history of its introduction, than important, as furnishing a considerable amount of sugar to continental Europe. The stems of *Indian corn* (*Zea Mays*) also yield this sugar; so do parsnips, carrots, and onions, in addition to many other vegetables.

Now the sweet product of the cane, the date, the maple, Indian corn, beet root, parsnips, turnips, and onions, is denominated, in general terms, "*cane sugar*,"

with which it is chemically identical; for although the raw juices of these several vegetables differ as to the character of their sweetness, and although the raw or yellow sugars derived from them, also participate in the difference, yet this is not referable to any difference in the sugar itself. It results merely from the presence of collateral and associated impurities. When all these are removed, as is the case with pure or *loaf-sugar*, the identity of saccharine material from all these various sources is readily demonstrated.

Glucose, or *grape sugar*, is sometimes denominated *uncrystallisable* sugar. This denomination is incorrect. It crystallises without much difficulty. Its crystals, however, cannot be made available—cannot be aggregated into loaves, like the crystals of ordinary sugar—cannot be retained in the form of crystal after much handling. It breaks down into little granular masses. as you see them here in a specimen of glucose which has been prepared from raisins. It is to this variety of sugar, that most of the fruits growing in temperate climes owe their sweetness; whereas the general tendency of fruits growing in tropical countries, is to the secretion of cane sugar. In addition to these varied sources, grape sugar can be manufactured by artificial means, which is not the case, as yet at least, with cane sugar.

In this country the manufacture of grape sugar has never been conducted as an operation of legitimate commercial speculation; although clandestinely, and for the purpose of sophisticating colonial muscovado sugar,

it was some years ago prepared rather extensively. Since the larger importation and lower price of colonial sugar, due to our late altered tariff, the preparation of glucose in England has been entirely discontinued. Probably this result was in some measure brought about by the potato disease, for potato starch was the material with which the operation of manufacture commenced. In France, however, the operation is still carried on, and with a legitimate object in view. Glucose is there used for the purpose of mixing with the "must," or recent juice of grapes, which, owing to insufficient ripeness, or other causes, may prove deficient in this element.

The process usually adopted for producing grape-sugar artificially, consists in boiling, for a prolonged period (thirty-six or forty-eight hours), a solution of starch in water, with a minute portion of oil of vitriol. By this curious process glucose results; and, by proper treatment, may be separated from the solution in which it is contained. A very trivial amount of oil of vitriol suffices, as I have said, to effect the change of starch into grape-sugar; and although the fact of the metamorphosis has long been known, chemists are not able even at the present time to give a consistent account of it. This much is certain, that the oil of vitriol originally employed, may be obtained finally without change. It has entered into no permanent combination, and must have effected the conversion of starch into sugar by the operation of what chemists term "*catalysis*."

Grape-sugar is also produced from starch by the

operation of *malting;* the starch in this case not being transformed into sugar immediately, but passing through the intermediate state of *dextrine.* I have hitherto considered starch as the starting-point of sugar artificially produced, but it is not the only one. *Gum* also, when dissolved in water and exposed to prolonged boiling with oil of vitriol in minute proportion, yields a similar result, as also does *lignine* or *woody fibre.* Hence, cotton or linen, or saw-dust, may each in turn become the source for yielding glucose or grape-sugar. But by far the most important source of grape-sugar for chemical study, is the sugar of the cane. Not that the latter is a source for economic purposes, as may readily be inferred, seeing that cane-sugar is by far the more valuable material. However, it so happens that grape-sugar is alone, of all the varieties of sugar, capable of undergoing *alcoholic fermentation;* hence, when a spirituous liquor results from cane-sugar, as a basis, the latter must undergo the primary change into grape-sugar. This change, indeed, is readily accomplished by various means; it is the chief cause of the difficulties with which the sugar manufacture is beset, and of the destruction which ensues. Not only is the change readily effected by prolonged boiling with water slightly acidulated by sulphuric acid; but acids generally, have this property; so, in like manner, have alkalies and alkaline earths; and, indeed, prolonged application of heat, even without the presence of either acids or alkalies, suffices to metamorphose cane-sugar into glucose. This

chemical property lies at the basis of all the leading difficulties which beset the sugar manufacture, whether in the colonies or in refineries. These difficulties I shall have to speak of hereafter.

Having already shown how cane-sugar may be distinguished from grape-sugar by physical appearances, supposing both to be in the *solid state*, it will now be well to indicate certain other means of distinction which apply to the two varieties of sugar *in solution*. Perhaps the most readily applied of these, is that devised by Trommer, and now called, after him, Trommer's test. It consists, in boiling the sugar to be tested with water, containing a mixture of tartaric acid, carbonate of potash or of soda, and sulphate of copper.

If some cane-sugar be put into a test tube and treated in this manner, no immediate alteration of appearance takes place; if, however, grape-sugar be similarly treated, a bright-red precipitate, the suboxide of copper, falls. This test is very reliable when applied with due caution, but the operator must always remember, in applying it, that cane-sugar is capable of changing into grape-sugar, by the operation of heat; hence no conclusion can be arrived at, after the operation of boiling has been prolonged to the extent of a few minutes; at all events, the conclusion deducible from such an experiment, will be relative merely, not absolute. *

* "The best cupreous solution for the purpose, is that of tartrate of copper in caustic or carbonated soda; this is a deep

The change into grape-sugar is the first which cane-sugar undergoes by the application of heat. If heat be still prolonged, the grape-sugar, in its turn, is changed into caramel; and if the heat be further prolonged, caramel is decomposed into various other bodies of acid nature, the qualities and composition of which have not been accurately made out; ultimately, by still further increment of temperature, these black compounds are decomposed into several volatile matters, which escape, and charcoal, which remains. Indeed, crystallised cane-sugar, as we shall hereafter discover, may be regarded as composed of twenty-four equivalents of carbon or charcoal atoms, or twenty-two of hydrogen, and twenty-two of oxygen; or, in other words, of twenty-four atoms of carbon, and twenty-two atoms of water.

A very striking illustration of the large amount of charcoal which sugar holds within itself, may be afforded

blue liquor, which, with the minutest addition of grape-sugar, is decomposed at a boiling heat, and a yellow hydrated dioxide of copper is thrown down, which, when collected on a filter, washed, and dried, assumes a red colour. Cane-sugar, to become sensible to this test, must be previously converted into grape-sugar, by boiling its solution with the addition of a few drops of sulphuric acid." "A still more delicate test of grape-sugar is the liquor obtained by mixing a solution of chloride of platinum with tartaric acid, and adding excess of solution of soda: when the smallest trace of grape-sugar is added to this liquor, and the mixture boiled, it blackens, and metallic platinum is thrown down, the weight of which may be resorted to as the indicator of that of the sugar." (L. Thompson.) Brande's Chemistry, vol. ii., p. 1184; edition 6.

by mixing it with oil of vitriol. I have here a portion of syrup—a saturated solution of sugar and water—and I add to it a portion of oil of vitriol; chemical action at once takes place; a peculiar odour is evolved, depending for the most part on the generation of formic acid; the whole mixture froths up; and ultimately, a black result, similar in appearance to charcoal, remains. Charcoal it is for the most part, but not exclusively, as may be proved by washing the entire mass with solution of potash; by which treatment a coloured solution results. Charcoal is not soluble in solution of potash, therefore the treatment I have pursued demonstrates the existence in this black compound of another body, or bodies. In point of fact there are several of these present, and they are of an acid nature, as may be inferred from the circumstance of their solution by potash. If the potash be neutralised by means of an acid, these acid bodies may be thrown down as a dark-coloured precipitate. I have already mentioned the circumstance, that their exact nature and composition are unknown. One, however, of these bodies, has received the name of *melassic* or *melasinic acid*, and it is to the existence of this that the dark colour of molasses or treacle is attributable.

Having thus given an outline of the chemical properties of cane-sugar, grape-sugar, and their chief derivations, let us now examine the composition of sugar. Every variety of this principle is made up of

carbon, hydrogen, and oxygen, in various proportions. The one remark applies, however, to all,—that the carbon and hydrogen exist in the exact proportion to form *water;* moreover, no variety of sugar contains nitrogen. This latter fact is expressive of the purpose which sugar subserves when taken as an aliment. It is unable to contribute nitrogen to the animal economy; but it powerfully contributes to the fixation of carbon in the form of fat; besides contributing to the animal temperature by the combustion of another portion of carbon.

I have already stated, that sugar may be regarded as a compound of carbon in union with the elements of water; this statement involving, however, no theory as to the condition in which the elements of water exist. The following diagram shews the composition of cane and of grape sugar, in their dry or combined state, and in their ordinary or crystalline conditions:—

DRY CANE-SUGAR (CARAMEL).

	Atoms.	Equivalents.	Per Cent.
Carbon . . .	24	144	47·12
Hydrogen . . .	18	18	5·76
Oxygen . . .	18	144	47·12
Caramel . . .	1	306	100·00

DRY GRAPE-SUGAR (GLUCOSE).

	Atoms.	Equivalents.	Per Cent.
Carbon . . .	24	144	43·24
Hydrogen . . .	21	21	6·31
Oxygen . . .	21	168	50·45
Glucose . . .	1	333	100·00

CRYSTALLISED CANE-SUGAR.

	Atoms.	Equivalents.	Per Cent.
Carbon . . .	24	144	42·10
Hydrogen . . .	22	22	6·43
Oxygen . . .	22	176	51·47
Crystallised cane-sugar	1	342	100·00

CRYSTALLISED GRAPE-SUGAR.

	Atoms.	Equivalents.	Per Cent.
Carbon . . .	24	144	36·36
Hydrogen . . .	28	28	7·08
Oxygen . . .	28	224	56·56
Crystallised grape-sugar	1	396	100·00

The *formulæ*, therefore, of these varieties of sugar will stand as follows—and, inasmuch as the oxygen and hydrogen are, in all these cases, in the same relative proportions to each other as in water, it has sometimes been customary, in theoretical discussions, to consider the sugars and their congeners as compounds of carbon and water, and to represent the crystallised sugars as containing a certain surplus of water, not chemically combined:—

Dry cane-sugar (Caramel) . $C_{24} H_{18} O_{18}$.
Dry grape-sugar (Glucose). $C_{24} H_{21} O_{21}$.
Crystallised cane-sugar . $C_{24} H_{22} O_{22} = C_{24} H_{18} O_{18} + 4$ HO.
Crystallised grape-sugar . $C_{24} H_{28} O_{28} = C_{24} H_{21} O_{21} + 7$ HO.

It is further obvious that both grape-sugar and cane-sugar, in their ordinary or crystallised conditions, may be regarded as formed upon the base of caramel; that is to say, a ternary compound of 24 atoms of carbon,

18 of hydrogen, and 18 of oxygen. The above *formulæ* also afford a consistent explanation of the effect of heat and certain other agents on cane-sugar, in changing it into grape-sugar and ultimately into caramel; for, if *crystallised* or *common* cane-sugar be regarded as caramel, *plus* four atoms of water, and dry grape-sugar as caramel, *plus* three atoms of water, the effect of heat in the conversion of cane into grape-sugar will consist in the evolution of one atom of water, and, afterwards, if two other atoms of water be evolved, caramel will be the result.

It appears, then, that the change is not less easy in practice than comprehensible in theory, from cane-sugar to caramel,—we have merely to go on applying heat, to continue evolving water, and the result ensues. Unfortunately, we cannot proceed in the other direction. In the *downward* change of molecular distribution—in a change towards *destruction*, all is easy; but no chemical process hitherto discovered can change caramel into grape-sugar, or grape-sugar into cane-sugar. A knowledge of this fact explains the destructive agencies which beset the sugar manufacture in every stage of its process, whether in the colonies or at home. Sugar can only be got out of the native juices which contain it, by the application of heat to promote evaporation; and heat, as we have seen, changes cane-sugar into other allied products. Nor is this the only difficulty the sugar manufacturer has to contend with. All vegetable juices which contain sugar, also contain various

other substances, which impede the crystallisation of sugar, and which, therefore, require to be separated by the addition of some chemical agent. For the most part, the chemical agent thus employed is *lime*, a substance which, I have already remarked, has a tendency to change cane-sugar into grape-sugar, grape-sugar into caramel, and caramel into other and lower products of decomposition. Thus is the sugar manufacturer beset with difficulties from this peculiar cause; and if we add the difficulties attributable to the dilute condition of naturally existing saccharine juices, and, as a consequence, the *time* heat must be applied in order to effect the necessary evaporation—also the tendency which, almost from the first stage of manufacture to the last, the saccharine juice has to enter into *fermentation*—some idea will be formed of the numerous causes which finally result in the large destruction of sugar to which I have adverted.

Having thus slightly sketched the theoretical circumstances involved in the manufacture of sugar, I will proceed to give a brief outline of its practice, commencing with the expression of juice from the sugar-cane, and the manufacture of muscovado sugar.

Of all the various natural sources of sugar, the cane is the most important. Not only does its juice contain more sugar, in a given quantity, than the juice of any other plant—save one, the palm-date—but it is pre-eminent above all, without any exception, in the quality of aroma. Specimens of cane-sugar, as I have already

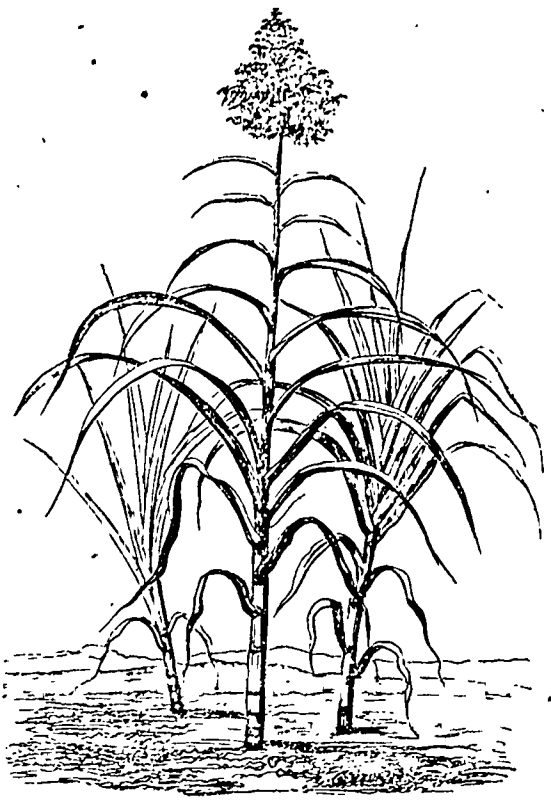
remarked, from whatever vegetable derived, are identical; therefore, when in a condition of absolute purity, cane-sugar from one source, is equally good as from another; but the impure, or yellow, otherwise termed "muscovado" sugars, differ extremely in the quality of being palatable, according to the source from which they are derived; not owing to any difference as to the sugar itself, but as to the kind of impurity with which the sugar may be combined. Thus the impure sugar extracted from maple-juice is offensive to most palates, and is only tolerated by the force of custom. To the yellow sugar from beet-root, the remark yet more strongly applies. No amount of custom has ever rendered it agreeable to the palate; hence, in all countries where beet-root sugar is produced, it is thrown into commercial channels, in the form of a refined, or pure article. To the yellow sugar of the date-tree juice the same remark applies, although not so forcibly. As regards muscovado sugar from the cane, however, the reverse obtains. To many palates it is even more agreeable than refined sugar, particularly when mixed with coffee; and, in countries where the sugar-cane grows, slices of it are commonly used instead of fruit, as a desert. The custom is very prevalent in Spain, where considerable tracts of ground are laid out in canes, for consumption in this manner.

The method of extracting the juice from the canes differs in different localities; but the obvious mechanical force of pressure is still universally had recourse to,

although various other methods, some of them highly philosophical, have been proposed. The usual machine employed in effecting this pressure, is the *sugar-mill*, of which there are numerous varieties. The simplest form of sugar-mill is that on the principle of a gigantic pestle and mortar, the pestle being moved by animal power. This plan has been followed since time immemorial in China and Hindostan; and the model of such a machine might be observed in the oriental division of our late exhibition in Hyde Park.

Sugar-mills employed by more civilised nations consist of cylinders, either arranged vertically or horizontally, capable of being regulated, as to distance from each other, by means of screws, and actuated by water, steam, or animal power. The operation of these machines will be evident without description. It suffices to remark, that the canes cut into convenient lengths, and separated from the upper portions, which are devoid of sugar, are subjected to the pressure of the mill cylinders, as often as may be deemed necessary. The expressed juice is now collected in appropriate vessels, and subjected to a treatment which will be presently described, and the bruised texture of the cane, termed *megass*, is stored as fuel. This is the general plan followed in most of the West India Islands, where, as the rule, no fuel but megass can be obtained. Nevertheless, in certain localities more favourably situated, the "megass" is subjected to further compression by means of Bramah's hydrostatic press, and with the result of yielding some

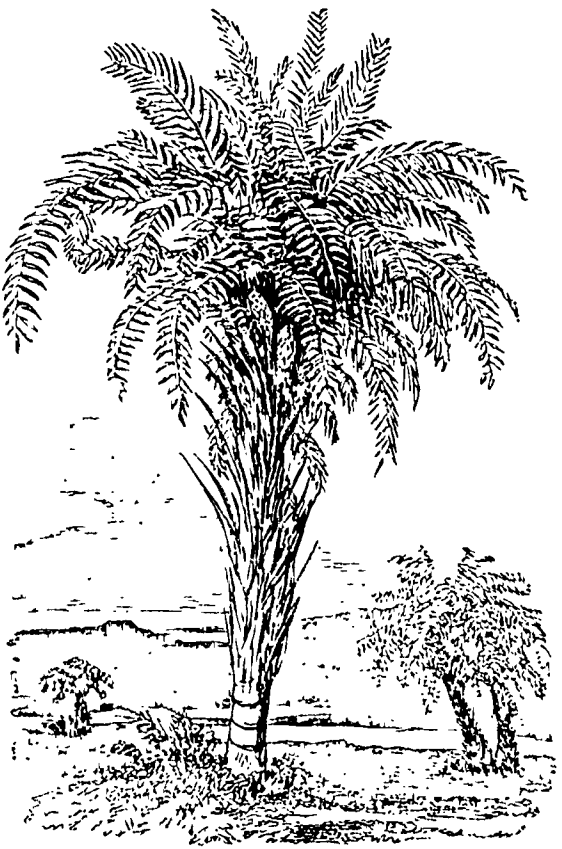
fifteen or twenty per cent. of rich juice; richer, indeed, it has been stated, than that flowing from the mill.



THE SUGAR CANE.

Before I proceed to detail the general process followed in treating the cane juice, it will be well to take a glance at the original amount of juice held within the tissue of the cane, as compared with the amount

obtained. This point has been investigated by several chemists, at various times, and at numerous sugar-



THE DATE PALM.

producing districts. The results are strictly accordant one with another: the cane is found to consist, in 100 parts, of 10 parts woody fibre, and 90 parts of juice.

Having regard to the enormous mechanical power brought into play by means of the sugar mill, we might assume from *a priori* consideration, that the major portion of this ninety per cent. of juice would be expressed. So far, however, is this from being the actual result, that the concurrent testimony of all observers who have turned their attention to this matter, agrees in representing the average quantity expressed as no more than fifty per cent. Such a loss as this is very startling: it depends on many causes; some referable to the mechanical conditions of the mill itself, some to imperfect manipulation, and others to prejudice. It must follow, from remarks which have gone before, that the efficiency of a mill, *cæteris paribus*, will be in direct relation to the proximity of the cylinders one to another. This proximity diminishes as the mill gets old; and although, by means of screws and bearings, the cylinders admit of being moved nearer to each other, yet the time and trouble involved in effecting this regulation, causes it frequently to be neglected. Much of the efficiency of a sugar-mill depends on the regularity with which it is fed. The great object to be kept in view is to supply the revolving cylinders with an even layer of canes. If this precept be not attended to—if the layer be uneven—then it follows that the thickest portion of the layer will be subject to the greatest pressure, leaving the thin edge of the layer to be acted upon to a greater or less extent. This is an objection to a vertical cylinder mill, which requires much more care in sup-

plying it with cane than the mill with horizontal cylinders; although the former, in many respects, is the more convenient. Nevertheless, however good in character the sugar-mill may be—however perfect in its state of repair—however careful those who supply it, when in operation, with canes—one cause of practical imperfection yet remains, an imperfection which attaches to the mechanical principles on which the sugar-mill is formed. It follows, from plain mathematical considerations, that the line of maximum pressure dependent on two proximate revolving cylinders, is indefinite in breadth; therefore the breadth of cane layer exposed at any one instant to this cylindrical pressure, must be indefinitely small. If the structure of the cane were totally devoid of elasticity, this small extent of pressure, at any one instant, would not matter; but inasmuch as it is elastic, and immediately expands after moving on from the line of maximum pressure, the expanding portion acts as a sponge would under similar conditions: it absorbs a portion of the juice which had already been expressed. This imperfection attaches to the very nature of the mill, and cannot be entirely overcome. Cognisant of this defect, and desirous of obviating it, Mr. Bessemer has invented a machine for expressing juice from sugar-canes by means of plane contact. When set in action, it effects the double purpose of cutting the cane into short lengths, and squeezing the lengths thus resulting.

Whatever process of expression be had recourse to, the general result is not the mere expression of saccha-

rine juice, but a certain portion of albuminous colouring and waxy matter, to an extent which may be judged of on comparing a little juice as it naturally flows from the extremity of a cane recently severed, with another portion of juice as it flows from the mill. This colouring matter, or albuminous and waxy material, although amounting in weight to an inconsiderable portion of the whole juice, must nevertheless be separated or destroyed. Whilst it remains associated with the sugar, the latter cannot be crystallised.

Certain chemists have endeavoured to extract all the sugar naturally contained in the cane, by proceeding on a totally different principle. Instead of expressing the juice, sugar, and associated impurities altogether, the idea has been entertained of cutting the cane into thin slices, by machinery, drying the slices by artificial heat, treating them by means of hot water, and evaporating the result. This plan is philosophical enough. It is just the plan a chemist might be induced to adopt in his laboratory. Every step of the operation is founded on correct chemical principles. The slicing operation brings the canes to such a mechanical state of comminution, that they can be dried with the minimum expenditure of heat, and in the minimum time. The drying operation coagulates the albuminous principle, just as white of egg is coagulated by heating; and the subsequent process of treatment with water effectually removes all the sugar. Why, then, it may be demanded, is the process not equally successful in practice, as it is unim-

peachable in theory? Various sources of difficulty exist. In the first place, the practical operator meets with a difficulty where he would little expect it. Sugar-cane is coated externally with a thin layer of silica or flint, which rapidly destroys the edge of the instruments employed in the slicing operation. Secondly, the operation of drying requires artificial heat, and thus involves the expenditure of more time, fuel, and general attention, than are compatible with the resources of sugar-growing colonies. Finally, the process of exhaustion requires water, in localities where water frequently cannot be obtained; and it requires hot water, where no fuel exists for heating it. All these circumstances conspire to impede the application of this elegant principle.

Returning now to the consideration of cane juice, as expressed by mechanical means, we find it to be a straw-coloured aromatic liquid, sweet and agreeable to the taste. Its density varies from 10 to 13 of Beaumé's saccharometer, equivalent to a specific gravity of 1070 to 1090, water being 1000. If allowed to remain at rest, without further treatment, at any natural temperature, but especially if the temperature be rather high, as we find it in tropical regions, the juice rapidly undergoes fermentation, and its sugar is destroyed. Hence, the operation of converting it into a crystalline state, begins without delay. The usual process of manufacture is as follows:—The juice being heated to a temperature of about 140°, a certain quantity of milk of lime—that is to say, quick-lime suspended in water, or in a portion of

cane juice, is added and well incorporated. The temperature is now gradually raised, care being taken that the juice does not boil. Gradually a thick scum rises to the surface of the liquid, which scum the operator takes care not to break. At length this layer of floating impurity cracks, indicating by the phenomenon that the clarifying juice underlying it may be subjected to further treatment. At this point either the scum itself is removed by skimming, or the juice is drawn away by a sluice or tap from under it, and is subjected to continuous evaporation, in a series of iron or copper pans, denominated "*teaches*," all hung over one common flue, and heated by means of the cane-refuse, or megass.

It follows, from a consideration of this arrangement, that the juice thus subjected to progressive evaporation continually diminishes, in bulk; the water being continuously evolved, and sugar left. If sugar were a substance indestructible by heat, when subjected to continuous boiling, this would be the simple exposition of the result; but we have seen that sugar cannot be heated without undergoing, to some extent, a decomposition, especially when acids, or alkalies, or alkaline earths are present; hence some idea may be formed of the destruction which sugar undergoes when subjected to the necessary process of evaporation. Indeed the whole of the *molasses* may be said to derive its origin from this destruction. All the sweet principle of healthy cane-juice is due to the presence of pure white crystalline sugar. Occasionally, on slicing a cane transversely, and

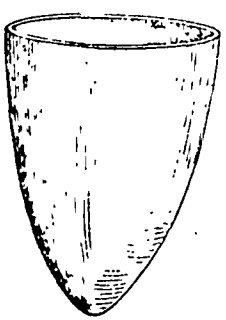
examining the sliced portion by means of a lens, crystals of white sugar may be seen; and even when this is not the case, they can be obtained by refined chemical processes. It follows, therefore, from a consideration of these facts, that molasses is attributable to sugar destroyed. The exact disposition of the evaporating pans, or teaches, is subject to much variation in different localities. The point aimed at, however, is in all cases the same: to subject the liquid, as it becomes thicker from evaporation, to an increased amount of heat. This is ordinarily effected by gradually ladling it from the furthest end of the flue, to that at which the fire is lighted.

Such is a general sketch of the most usual method of sugar boiling in the colonies. Its use is coeval with the history of sugar, and was formerly made the subject of eulogy by various advocates. In our own days, planters are by no means satisfied of its excellence, and numerous modifications have been proposed or introduced. Respecting these I shall offer no remarks just now; the most important—the most philosophic instrument, ever applied to the manufacture of sugar, is unquestionably the *vacuum-pan*, which will more naturally present itself for our consideration under the head of "refining." For some reason or other, the vacuum-pan has never been largely introduced into the colonies.

The chief disadvantage attaching to the ordinary arrangement of the colonial evaporating pans, is the impossibility of lessening or increasing the amount of heat under

one pan, without equally affecting all the rest. The advantage of the arrangement consists in its admitting the employment of megass as fuel, the blazing flame of which is well adapted to play along an extended flue.

The last and smallest pan of the series—that hung over the hottest part of the flue—is denominated the skipping teache. From it the evaporated juice, when reduced to the required density, is removed by means of ladles, or other adequate contrivances, and placed under conditions favourable to crystallisation. These conditions vary in different parts of the world.



CLAYING MOULD.

In Cuba, Brazil, Spain, and other sugar-growing regions, where the process denominated *claying* is had recourse to, the sugar is removed from the skipping teache, and poured into large earthenware conical moulds, each having a hole stopped with a fragment of cloth or paper at its apex.

The moulds are not filled all at once, but gradually. A skipping having been poured in, is allowed to crystallise; a second skipping is now added, and incorporated by stirring with the crystals already formed. Thus the operation is repeated until the cone has become completely filled, when it is allowed to stand at rest until cold. The cone is now unplugged—that is to say, the aperture in the apex is opened—and, being so placed as to stand over a large earthen pot, it is allowed to drain. By this

treatment most of the uncrystallised matter, to which the general term "molasses" is applied, drains away, leaving the crystallised sugar behind. The latter, nevertheless, is not pure. Were it pure, its colour would be white, not yellow or brown. The greater portion of uncrystallised impurities will have drained away, but not all. Each crystal of sugar is enveloped by a coating of molasses, for the removal of which the process of claying, as it is termed—it might be termed *washing*—is had recourse to. The operation of claying is prosecuted as follows:—A thin magma of clay and water being made, is plastered on the base of each sugar-loaf as it stands in the cone. Gradually the clay evolves water, which, percolating gently from base to apex, carries much of the yellow colouring matter before it; and leaves the crystals or grains comparatively white. The operation of claying is repeated again, and usually a third time, in Cuba, Brazil, and Spain; which repetition conduces to the whiteness of the sugar. It is not possible, however, so to purify sugar by claying, that no subsequent operation of refining will be necessary.

A slight consideration of the nature of the claying operation will render apparent the fact, that it must be a destructive operation. With whatever degree of slowness water may be evolved from the clay, still a portion of sugar will be liquefied.

The operation of claying is not generally had recourse to in British sugar-growing colonies; the purifying operation ceasing at that point when all the molasses

which is capable of spontaneous percolation has been removed, yielding the crystalline or semi-crystalline sugar, to which the general term "muscovado" is applied. There would seem no reason why the crystallising process as adopted in Cuba, Brazil, and Spain, should not be also employed in cases when the production of muscovado sugar is desired. It appears to be simple; based on correct scientific principles; easy of application, and effective. It is not adopted, however, by the sugar producers of our colonies, but a plan, theoretically less efficient, whatever excellence it may have in practice—and this is a disputed point—is followed. The plan adopted is this:—The thick evaporated juice, immediately on being ladled from the teache, is poured into large shallow tanks only a few inches deep, where the syrup is rapidly cooled into a semi-crystalline mass, which after a time is dug out and packed in casks: through the end of each cask is drilled a hole lightly stopped with a plaintain leaf. By this arrangement the uncrystallised material or molasses is allowed to percolate away, as it does to a considerable extent, leaving the remaining sugar in a condition more or less dry.

A consideration of the two modes of crystallisation just described will render it manifest that the flat shallow vessel in British colonies embodies the worst theoretical conditions for inducing crystallisation, as the large cone embodies some of the best.

Hitherto, however, the British West India sugar-grower has not endeavoured to free his staple from the

whole of its molasses. He has been guided by the idea—a most fallacious one—that the heavier he could pack his casks, the more his profit; omitting to take into consideration the amount of molasses lost in the holds of ships, and pumped into the sea.

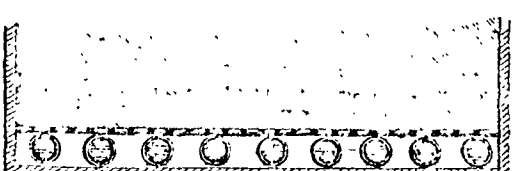
Having thus given a slight outline of the colonial preparation of sugar, we come now to the operation of *refining*, in conducting which, many scientific principles are brought to bear, and much ingenuity is displayed.

The material subjected to refining is muscovado sugar, of which the duller tinted varieties are preferred, the yellow kinds being almost exclusively monopolised by the grocers, for sale in the original or muscovado form. In order to entertain a just appreciation of the refining process, we must remember the object desired to be accomplished by it. Muscovado sugar is a mixture of pure crystalline white sugar with various colouring matters, some soluble, others insoluble; these matters it is desired to remove. We have already observed that a considerable amount of colouring matter of a certain kind may be removed by a washing process; in this way may the more soluble colouring matters be disposed of. There exist, however, in muscovado sugar, various substances which no amount of washing can separate.

The first operation in the manufacturing process of sugar refining consists in obtaining a solution, or syrup. Formerly, this was accomplished by means of heating sugar and water, in the desired proportions, over an open fire—a plan which for some time past has been universally

discarded, in England at all events; and steam-heat is employed instead. By the substitution of steam for the open fire, all danger of absolutely burning the sugar is obviated. Nevertheless, steam is not free from injurious agencies, giving rise to a decomposition of sugar not unlike the result of ordinary burning; and the extent to which these agencies are developed, depends, *cæteris paribus*, on the pressure of the steam employed,—supposing it to be applied to the purposes of heating a saccharine solution by injection into the latter.

Two methods of applying steam for the purpose of effecting solution are followed. One, and by far the most usual, consists in exposing the sugar and water to the action of naked jets of steam injected into it from a series of perforated tubes of iron or copper, ramifying below a false bottom placed across a rectangular metal tank. This tank is known by the technical name of the "blow-up" pan, and the general operation is denominated "*blowing-up*,"—a name expressive enough, as will be admitted by any one who has been present during the



SECTION OF BLOW-UP PAN.

operation, and has listened to the deafening noise occasioned by the escaping steam. By means of this application of naked steam, the operation of solution proceeds

with great rapidity. Not only do the steam-jets supply the source of heat, but the means of agitation also—very little stirring being required.

Practice has determined, that steam, when thus brought into naked contact with a sugar solution, is more injurious than when the solution, confined in a vessel, is heated by application of steam to the vessel externally. Hence, in several refineries, the blow-up pans have given place to other vessels, constructed so as to take advantage of the latter principle. The process of solution, however, as thus conducted, is much slower, and the mixture, during solution, requires to be assiduously stirred.

In refineries, the operation of effecting solution—of "*blowing-up*,"—is not applied to weighed or measured portions of sugar and water, but portions of each are thrown in according as the operator may deem necessary, his guide throughout being the saccharometer of Beaumé. The sugar to be employed is scattered loosely over the floor, and the workmen throw it into the solution tank, like so much earth, by means of spades.

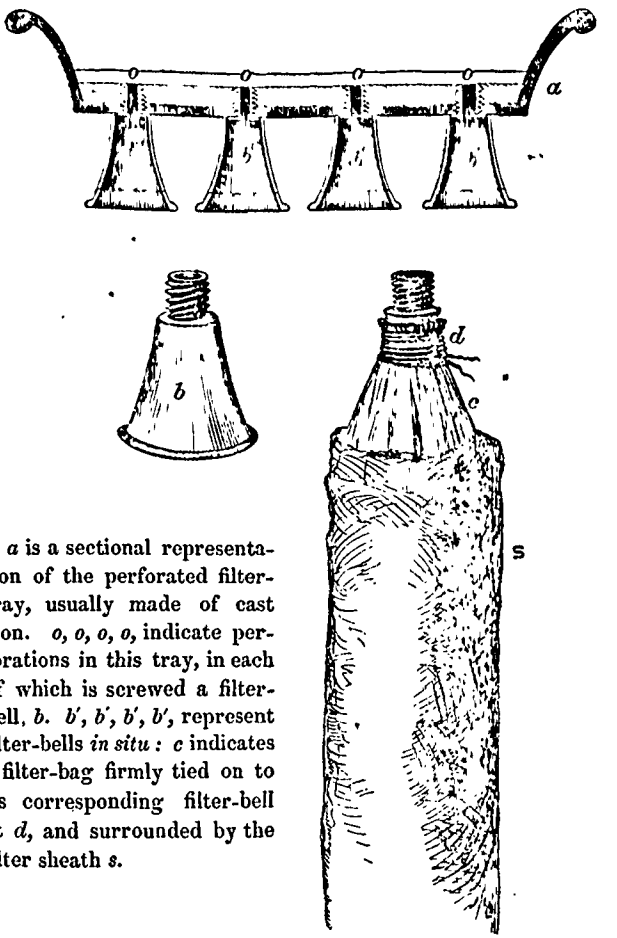
Reference has been made to a solution of sugar and water alone; in practice, however, a portion of lime water is added, and a quantity of bullock's blood, technically called "*spice*," the agency of which, in contributing to the process of refining, will be seen hereafter. As regards the density, or specific gravity of the liquid at this stage of operation, there may be considerable variation. No two refiners are exactly agreed on this

point. Perhaps, however, the density of 31° Beaumé at a boiling temperature—equivalent to the density of about 28° B., at a temperature of 75° F., may be regarded as the best.

We have now to consider the agencies of *lime water* and *bullock's blood*. The first is said to be employed for the purpose of neutralising acidity; but this assumption is incorrect, or rather it is incomplete. In the first place, if mere neutralisation of acidity were required, accepting the term acidity in its ordinary sense, chalk should succeed as well as lime, and its employment would be free from many risks of injury to sugar, with which the use of lime is attended: secondly, the existence of an acid, in unfermented sugar, is hypothetical; and lastly, if the antacid quality of lime were especially desired, lime-water, containing as it does, so little of that earth, would be a very inefficient medium of administration. The real use of lime-water appears to be this:—its lime forms a chemical union with various colouring matters existing in muscovado sugar, and yields a flocculent precipitable substance, which, being subsequently enveloped in the albumen of the blood serum coagulated by heat, rises to the surface in a scum, and may be removed.

When the mixture of sugar and water has become sufficiently dissolved, and the rougher portion of its impurities has been skimmed off, a sluice or tap is opened in the bottom of the pan, and the fluid is allowed to escape into a tray, communicating with a very ingeni-

ous *filtering apparatus* of cloth, which will now merit our attention.



a is a sectional representation of the perforated filter-tray, usually made of cast iron. *o, o, o, o,* indicate perforations in this tray, in each of which is screwed a filter-bell, *b*. *b'*, *b'*, *b'*, *b'*, represent filter-bells *in situ* : *c* indicates a filter-bag firmly tied on to its corresponding filter-bell at *d*, and surrounded by the filter sheath *s*.

FILTER-BAG AND SHEATH, WITH APPARATUS.

The tray into which the dissolved sugar is caused to flow, is supplied with numerous apertures, each of which is cut with a screw, into which a short brass tube may be inserted. To each of these brass tubes is firmly tied a filter-bag, which may be compared to a pillow-case closed at one extremity; and each of these bags is thrust into another bag of coarse net-like material. This latter bag is technically called a *sheath*. From a consideration of this arrangement, it will at once be seen that the filtering material is adapted to the conditions of furnishing a large extent of surface in a small extent of space,—conditions eminently desirable in a sugar refinery, where operations on so large a scale are conducted in premises of dimensions so restricted.

There are many practical points in connection with the cloth or bag filtration process, highly necessary to be taken cognisance of by the practical refiner, but into the details of which I cannot be expected to enter here. One of the most important of them is to fill the bags with fluid in the quickest time possible; for until they are completely full, the filtered liquor remains foul. Attention must also be paid to heating the filtering apparatus to a proper temperature before the fluid is allowed to escape from the blow-up pan. This elevation of temperature is accomplished, no less simply than efficiently, by hanging the filter-bags in a small box or chamber, into which steam jets may be either turned on or turned off at pleasure. As the flow of liquor goes on through the filter-bags, a workman examines a portion

from time to time as to brightness, collecting it in a wine-glass, and observing it by rays of transmitted light. Refiners are very particular in regard to the brightness of their liquors, any turbidity affecting the sugar-loaves hereafter to result. Until this degree of brightness has been obtained, the "filtrate," or fluid coming through the filter-bags, is turned into a receiver called the *foul-liquor tank*, and the result thrown back into the blow-up pan.

If the solution be examined as it flows through the filtering tissue, after having acquired its maximum clearness, it will be found bright, but dark, the colour being much like that of port wine. For the removal of this colour, another agent, namely, *bone black* or *animal charcoal*, is employed; and this leads me to speak of the general property of decolouration possessed by this agent.

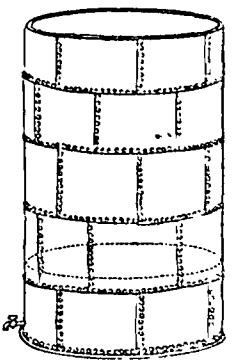
If a portion of red-wine, of porter, of tincture of litmus, and generally of any coloured liquid, be agitated with animal charcoal, and subsequently filtered—or still better, if the coloured liquid be passed through a layer of the animal charcoal used as a filtering agent, decolourisation, more or less complete, will ensue. Chemists avail themselves of this property extensively in their laboratory operations, and bone-black has become, within the last thirty years, one of the most important of all chemical agents employed in the refining of sugar.

When employed as a means of decolourisation in the laboratory, animal charcoal must be pure, in order to avoid contamination resulting from the carbonate and phosphate of lime wherewith it is associated in common

bone-black; sugar refiners use bone-black without any further preparation than reduction to a granular form. Now, bone-black is composed of about ten per cent. actual charcoal, mixed with ninety per cent. of phosphate and carbonate of lime, chiefly the former. Nevertheless, this material exercises a more powerful decolourisation on yellow sugar than does pure animal charcoal—a fact which seems to point to some decolourising agency attributable to the phosphate and carbonate of lime. It may, however, be attributable to the diffusion of charcoal particles over a larger space than they would otherwise occupy, by the interposition of phosphatic and other particles. The whole rationale of the decolourising effects of animal charcoal, however, is involved in great obscurity.

In refineries, the method of employing bone-black for the purposes of decolouration is as follows:—A large cylinder of iron or copper, six or eight feet in diameter, and from twelve to fifteen, perhaps more, in height, is packed with the granulated charcoal, resting on a false bottom foundation of hollow wood-work and stout linen cloth. The charcoal usually extends from the false bottom upwards, to within a certain distance, perhaps two or three feet, of the open end of the cylinder, the remaining space serving as a reservoir for the sugar solution, which gradually percolates, and is allowed to escape. Such is the usual method of conducting the filtration of the sugar solution through the bone charcoal; but various modifications of it are

found in different refineries. Sometimes the charcoal cisterns, instead of being allowed to remain open at the top, are closed, except where a hole is left for the insertion of a tube communicating with a separate reservoir, in which the charcoal is packed, and removed through a man-hole, the door of which can be screwed on or removed at pleasure, precisely as is accomplished in the boiler of a steam-engine. Sometimes, again, in order to avoid perforation of the floors of the manufactory, which these tall cylinders necessitate, rectangular tanks, arranged on one floor, are substituted; but in all cases the general routine of filtration is the same.



CHARCOAL FILTER-TANK.

The decolourising effect of bone-black, as evidenced in the result, is most extraordinary. The solution, as it comes from the filter-bags, is, as I before remarked, of a port-wine colour: as it flows from the charcoal, it is not only bright, but as colourless as water. Gradually, however, as the process of filtration goes on, the filtered result grows tinted, until at last, having acquired a hue something like that of dark sherry, the filtration must be stopped, and the charcoal washed, preparatory to its removal. The operation of *charcoal washing* is in itself one of some delicacy. Water is poured on, and allowed to percolate the mass, until the escaping fluid

indicates zero, or something near it, on the saccharometer; thus proving that all the sugar has been removed. If the operation be judiciously conducted, very little sugar will remain behind; the refiner's grand object consisting in removing the maximum of sugar with the minimum amount of water. The charcoal is now taken out of the cylinders or tanks which held it, dried, and reburned.

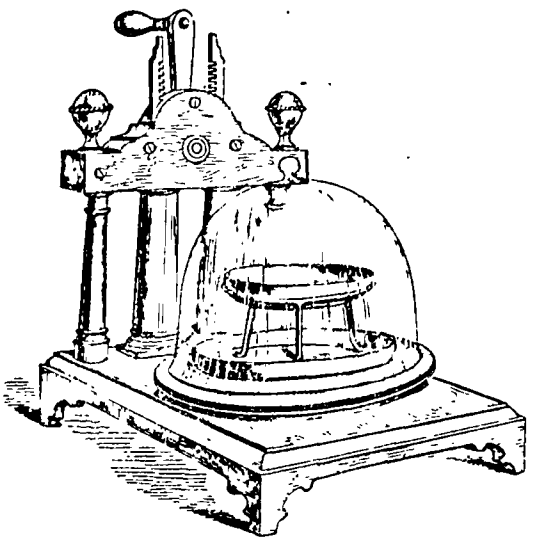
It is a curious fact, and one of which no sufficient explanation has been given, that bone-black does not exercise its maximum degree of power on *weak* solutions of sugar. A solution, having a density of about 26° to 28° of Beaumé, equivalent to specific gravities of 1221 and 1241, is the best. Hence this density should be always aimed at by the refiner; and although many circumstances, in the course of actual working, may necessitate variations above as well as below this limit, to some slight extent, the specific gravity indicated cannot be materially departed from without bad consequences.

Having now traced the sugar originally dissolved in the blow-up pan, through the filter-bags, and thence through the charcoal, we may examine the process of *boiling*, which follows next in order. This process, conducted as it is now almost universally, by means of the *vacuum-pan*, is one of great beauty. In no case have refined chemical laws been more successfully applied. In few cases have so many difficulties, chemical and mechanical, been more completely vanquished.

Before describing the construction of the *vacuum-pan*, it will be well for me to indicate the principles upon which its operation depends. Let us begin, then, by an investigation of the phenomenon of *ebullition*. The *boiling* of a liquid results when a sufficient amount of heat has been imparted to dissever its particles, and to cause their evolution in the form of vapour. We must, therefore, regard heat as occasioning this result in virtue of its repulsive force,—repulsive as between the particles of fluid themselves; and repulsive as between the fluid considered as an aggregate, and the pressure of superincumbent air. Hence it follows that *atmospheric pressure* retards, or has a tendency to prevent, ebullition; and if this retarding force be removed, the boiling of any given liquid will, to that extent, be facilitated; and hence it is that many liquids of great volatility—liquids of which *ether* may be selected as the type—can be made to boil by the mere removal of atmospheric pressure, at common temperatures. This fact can be demonstrated by placing a tube of glass containing a little ether, under the receiver of an air-pump, and exhausting the air, when the ether evolves vapour so rapidly, as to cause violent ebullition.

This increased development of vapour by the reduction of atmospheric pressure, is of constant application in the laboratory. Many substances are injured, or destroyed, when desiccated, or when their solutions are evaporated by heat ordinarily applied; although most bodies, however delicate, may be subjected to desiccation,

or their solutions may be subjected to evaporation, by means of the *air-pump*. Suppose, for instance, it were required to evaporate away all the water of an aqueous sugar solution, and to obtain all the sugar in a crystalline state: the experimental chemist would accomplish



EVAPORATION BY MEANS OF THE AIR PUMP.

this in the following manner. He would put the solution to be evaporated, under the receiver of an air-pump, along with a shallow vessel containing oil of vitriol. He would now exhaust the receiver of the air-pump; the consequence of which would be, an increased evolution of vapour from the sugar solution. The vapour

might be removed continuously by a prolonged working of the air-pump; but the operation would be troublesome, and the oil of vitriol placed under the receiver renders the continuous working unnecessary. This substance being strongly attractive of water, absorbs the aqueous vapour as soon as it is evolved; and thus the process of evaporation goes continuously on.

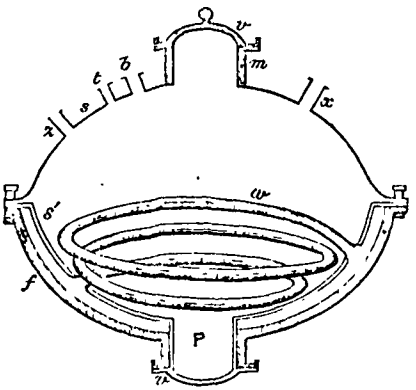
In the appended diagram, the upper capsule is supposed to be filled with the sugar solution, resting on a tripod of glass, placed in another capsule, containing oil of vitriol.

Such is the process as it would be prosecuted by the chemist in his laboratory. It is, however, clearly unadapted, in its present state, for adoption on the large scale. If applied at all, it must be considerably modified. Now, this modification is very ingeniously, and very satisfactorily effected, by means of the *vacuum-pan*, an instrument for which we are indebted to the late Mr. Howard, and which is a lasting evidence of his constructive skill.

I shall now proceed to give an outline of the various parts of the *vacuum-pan*, availing myself of the beautiful models which are before you, and which have been kindly furnished by Messrs. Shears, of Bankside, to facilitate my description.

The vacuum-pan consists of two shells of copper, of spherical, or spheroidal curve, *s* and *s'*; the edges of both are flanged, and the flanges screwed together. The lower of these copper shells is surrounded exter-

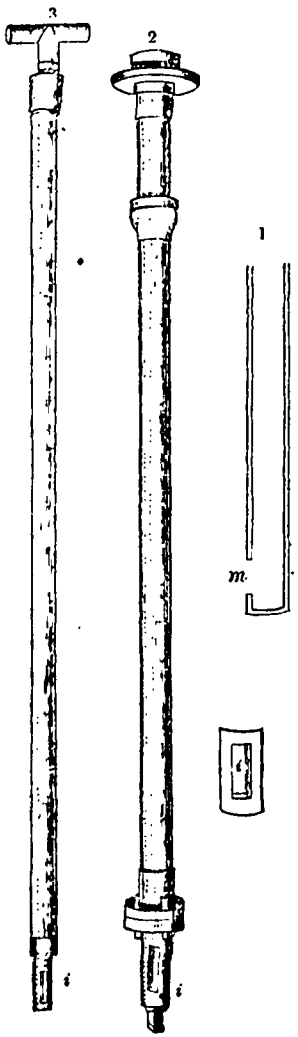
nally, by a steam-jacket, *f*, by means of which the contents of the vacuum-pan may be heated; and internally,



VACUUM PAN.

there ramifies a spiral copper worm, *w*, the intention of which is similar. Through the middle part of the lower copper shell, and through the steam-jacket which immediately surrounds it, is an aperture, P, capable of being shut or opened at pleasure, externally, by means of a valve with ground edges. This aperture is for the purpose of allowing the contents of the vacuum-pan, when sufficiently boiled, to escape. Directing our attention to the apertures in the upper copper shell, we find them more numerous. First, there is a *man-hole*, *m*, exactly similar to the man-hole in the boiler of a steam-engine, through which a workman enters for the purpose of cleaning the interior, effecting repairs, &c. This large aperture, like the

corresponding one immediately opposite, in the lower section, is capable of being accurately closed by means of a valve with ground edges. The next apertures to be described, in the upper section of a vacuum-pan, are those for admitting a *barometer* and a *thermometer* respectively, *b* and *t*, each being inserted through its own air-tight packing. Then comes an aperture through which the sugar solution is introduced, *x*; and, lastly, one, *z*, for the very ingenious purpose of allowing a portion of the contents of the pan to be withdrawn, without letting in air, and consequently destroying the vacuum. It is exceedingly difficult, without actual examination, to give a clear notion of the method by which this problem is solved. A general description, however, is as follows:—Into the aperture is securely fastened one end of a brass pipe, air-tight of course, and projecting its other end to within six inches of the lowest part of the vacuum-pan. This lower end, which, when the pan contains its charge, is necessarily covered by the latter, is supplied with a rotatory spill like the spill of a cask-tap, and which may be turned off or on at pleasure, by means of a key, termed "the proof-stick," which projects to the bottom of the sheath. When turned on, the little excavation (*i* in fig. 2 of the subjoined diagram) is made to coincide with the lateral aperture (*m* fig. 1) of the sheath, and the pan is said to be open. We will suppose, however, the operation of taking a proof to commence when the pan is *shut;* in other words, when the excavation in the spindle does *not* coincide with the lateral

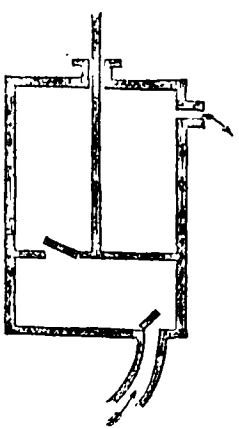


orifice in the sheath. Whilst the arrangement remains as described, the long key or proof stick (3) is thrust down; its lateral aperture (*i*, fig. 3) being made to correspond with the lateral aperture of the spindle represented in fig. 2. The proof-stick being now turned through an arc of two quadrants, both its own lateral aperture, and that of the spindle revolving with it, are brought into coincidence with the lateral aperture (*m*) of the sheath; and the sugar solution flows into the cup-like depression, or lateral excavation of the proof-stick. Supposing the latter now to be removed *without turning*, the vacuum would be destroyed; but if it be turned back into its original position, through an arc of two quadrants, so as to be no longer in coincidence with the lateral aperture of the

sheath, and then removed, a portion of sugar solution will be brought away, without in any manner affecting the vacuum.

It would be out of place, in a lecture of this kind, to explain all the various working details connected with the use of the vacuum-pan. I shall content myself with sketching a general outline of these, referring you to systematic works for particulars. Firstly, then, how does the liquor get into the pan? This is very easily accomplished by taking advantage of the suction power of the instrument attached to the vacuum-pan, for the purpose of creating exhaustion, and termed an "air-pump," although it is not an air-pump, in the sense of the instrument commonly bearing that name. It pumps more water than air, and without water it will not act. You may readily suppose, that if a very large air-pump, such as we use in laboratories, only much exceeding the latter in size,—you may easily suppose, that if such an air-pump were attached to a vacuum-pan, already containing liquid sugar solution, and that liquid heated by means of the steam-jacket externally applied, and of the worm-coil internally, the *tendency* towards a vacuum would be induced, and ebullition, at a reduced temperature, would ensue. In practice, however, the use of such an air-pump as this would be altogether out of the question. In the first place, its size, as compared with that of the vacuum-pan itself, would be enormous. In the second place, the delicacy of its valves would be such as to render them soon worthless; hence some modi-

fication of the common air-pump, is desirable. If we cannot employ an air, or rather a steam-pump, the first suggestion that occurs is, whether the steam might not be condensed into water, and the water pumped away, instead of the steam itself? This suggestion has been fully carried out, in what is called the *air-pump* of a vacuum-pan, and which is, in every respect, similar to the air-pump of a low-pressure steam-engine. It is an instrument of the simplest possible construction, merely consisting of an iron cylinder, into which fits a piston, supplied with one or more metal door-like valves, opening upwards. The action of such a pump as this will be evident from a mere examination of its parts. The piston being pressed down, the door-valve *will have a tendency to rise*, and, being raised up, the door-valve *will have a tendency to fall*. Now, whether the tendency be brought into active operation or not, will depend altogether on the medium with which the pump-cylinder may be filled.



AIR-PUMP.

Any one conversant with the nature of pumps will at once see, that such an instrument as this could not pump air effectually, inasmuch as large volumes would pass between the valve and its vent. No less obvious is it that such a pump would be very efficient, provided the object

were to pump water. It follows, therefore, from a consideration of these peculiarities, that the vapour evolved from the solution under ebullition must pass into an intermediate vessel, and become condensed, before this so-called air-pump could act. Accordingly, the latter, instead of being joined immediately to the vacuum-pan itself, is joined to an instrument termed the *condenser*, which, in its turn, I shall now proceed to describe.

Condensers assume various modifications, both in low-pressure steam-engines and vacuum-pans. They resolve themselves, however, into two classes, each having its own distinctive type. Either condensation is effected by the injection of water amidst the steam, or the water is made to circulate through a series of tubes, with which the steam comes into contact externally. Condensers of the former type are the most simple—the most general. I shall, therefore, direct your chief attention to them.

An *injection-condenser* is a very simple instrument, merely consisting of a large cylinder, having within it a tube, or tubes, communicating with a tank of water externally, and perforated. The consequence of this arrangement is, that so soon as the air-pump is set in action, jets of water escape from these apertures, and, rushing amidst the steam, convert it into water, now easily recoverable by the pump.

Well, it follows from the combined agency of all these appliances, that the refiner brings his dense sugar solution to a state of violent ebullition, at a temperature

rarely exceeding 150° Fahr., indeed much lower if required, and thus avoids much of the injurious consequences resulting from the application of heat. Nevertheless, a considerable amount of destruction is effected, even by the vacuum-pan, as may be recognised in the final result; for though the liquor originally exposed to evaporation may be, and frequently is, absolutely without colour, the result, after boiling, is more or less yellow, and the amount of tint is always proportionate to the degree of heat, and time of its application.

So soon as the sugar-boiler has determined, after frequent trials, that the contents of the vacuum-pan have been boiled sufficiently long, he opens the valve situated in the lower hemisphere of the pan, and allows the charge to escape into a vessel placed immediately below the vacuum-pan, usually on another floor. This vessel is in construction like the lower half of the vacuum-pan; that is to say, it consists of a copper shell, enveloped in a steam jacket externally. It, however, has not, like the lower segment of a vacuum-pan, a copper spiral, or worm. The heating is exclusively accomplished by means of the jacket. This vessel, just described, is termed the "*heater*," and sometimes by an apparent anomaly, the "*cooler*." The origin of the apparent discrepancy of terms is as follows:—At whatever temperature a solution of sugar be boiled, it must be potted at a temperature lying between 70° and 85° Fahr. Now, supposing the old plan of boiling, namely, *open pan boiling*, to be employed, involving a final

temperature of not less than 230° Fahr., frequently one still higher, it is evident that the vessel in which the evaporated magma is poured, before potting, is in function a cooler. Supposing, however, the *vacuum-pan* to have been the agent employed for accomplishing evaporation, involving a temperature generally lower than 160° Fahr., it is evident that the vessel having for its function to raise the magma to a temperature of 170° or 180° Fahr. is a *heater*. Hence the apparent discrepancy of terms.

The use of this heater is one of considerable delicacy, and involves the well known chemical principle, that there is a certain range of temperature at which solutions capable of undergoing crystallisation possess a certain maximum tendency to assume that state. When the vacuum-pan has been used, the charge ought to have assumed a distinctly crystalline state during the act of boiling—except, indeed, the charge be of a kind denominated *low* by the refiner; that is to say, unless it contain large amounts of glucose, and black colouring matter. Such material cannot be made into loaves, and only furnishes those brown sugars, of refinery produce, termed "*pieces*" and "*bastards*." Whether the charge have assumed the crystalline shape or not during the process of boiling, the object intended to be subserved by the heater is that of still further developing the crystalline action. This is accomplished by elevating the temperature to a certain degree, according to the nature of the charge; good sugar requiring less heat

than sugar which is low. Perhaps, for first-class loaves, the degree of 175° Fah. is best.

This increase of temperature is accomplished by means of the external steam-jacket; and whilst the

THE FILLING HOUSE.

temperature is getting up, men continually agitate the mass by means of a paddle of peculiar construction.

The next operation consists in what is technically called *filling out*. By means of vessels something like coal-

scuttles in shape, the contents of the heater are removed, and poured into moulds of copper, iron, or earthenware, the hole in the apex of each mould being plugged by stoppers of brown paper. The next operation varies according to the size of the moulds.

If the object of manufacture be to prepare that class of sugar-cones to which the term *loaves* is technically applied, that is to say, cones, the weight of which does not exceed fourteen pounds—the sugar-magma, as soon as it has consolidated on the face or *base* of the mould, is broken, and stirred by means of a flat wooden spatula, technically known as a "*hauling-knife.*" Cones of sugar exceeding fourteen pounds in weight, are not considered loaves in commerce, but are known under the name of *lumps, Prussian lumps, titlers,* &c., according to their weight. It is not usual for these to be subjected to the operation of hauling.

As soon as the contents of the moulds have well crystallised (for the accomplishment of which the time materially varies, according to the size of the mould), the paper stoppers are removed, a brad-awl is thrust a few inches up into the substance of the crystallised contents, and the moulds, thus unstopped and pierced, are placed to stand each over and upon an earthen pot, in order that the non-crystallised liquid matter may drain away. Some manufacturers do not employ pots, but racks—the aggregate syrup of many hundred, or, it may be, thousand cones, being collected by gutters, all ending in one general reservoir. In either case, the object is similar.

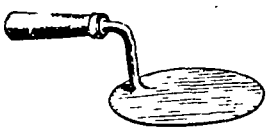
However white the original solution of sugar might have been, the operation of boiling, even when conducted by means of the vacuum-pan used at the lowest eligible temperature, and with every care, effects a certain amount of destruction, and therefore discolouration. Not only is the first syrup which percolates from the pierced cone not perfectly white, but the sugar from which it flows is not perfectly white—each crystal being surrounded with a coloured coat, so obstinately attached, that nothing less than a process of washing can remove it.

Several variations of this *washing* process have been brought at different times, and by different refiners, into operation. The oldest, and not the least efficient, consists in the application of *clay magma* to the face of the cones, exactly as already described when treating of the manufacture of *clayed sugar* from the original cane-juice. This form of washing is technically known by the name of *claying—claying proper*, as we will call it, by way of contradistinction to a process now almost universally employed in refineries, and to which the term claying is also given, although not a particle of clay is used. As now conducted in refineries, the operation of claying consists in the application of a thick magma, or mortar, of sugar and water to the face or base of the sugar-cone, instead of clay, as originally used. The operation is thus performed. By means of a triangular leaf of iron, a portion of the base of each sugar-loaf or

lump is cut out, and being incorporated with water until a material having the consistence of paste results, the material is superimposed on the base of each cone. The action of this superimposed material is similar to the action of wet clay, only not so destructive to the sugar loaf. Portions of its fluid gradually percolate through the loaf, carrying before them the coloured syrup. It is evident that, by repeating this operation of claying, as it is termed, a sufficient number of times, the sugar-cone under treatment might be rendered quite white. In practice, however, this treatment is not adopted, the claying process, as it is called, being merely used as a preliminary operation to that of *liquoring*, now to be described.

The *process of liquoring* involves the obvious principle, that water which has already become saturated with sugar, at any given temperature, cannot, at that temperature, dissolve any more. The refiner prepares, by a process hereafter to be described, a saturated solution of pure sugar; this he stores away, usually on the top floor of his manufactory, and preserves under the name of "*fine liquor*," or "*magma liquor*." Its density, at a temperature of 60° F., being not less than 33° Beaumé, equivalent to a specific gravity of 1,091, there is no fear of fermentation taking place; it may be kept for any length of time. The operation of liquoring is performed on loaves or lumps, which have already been subjected to the operation of claying. We had better retrace our steps to the point where we

left off with the description of a clayed loaf. The clay, or mortar of sugar and water, we assumed to have been superimposed, to have driven portions of the coloured syrup before it, and gradually to have become dry. The next object of the workman consists in giving to this sugar-clay an even surface. This he accomplishes by means of an instrument termed the *bottoming trowel*. Magma liquor is now poured on, to the extent of some inches, and allowed to percolate through the whole cone. The operation of liquoring is exceedingly beautiful. Not only, by means of it, is the dark-coloured syrup expelled, but the remaining sugar increases in weight by the aggregation of fresh particles yielded by the fine liquor. Thus we have weight actually conferred by the process of washing, instead of weight lost. For some reason, the combined operations of claying and liquoring, as now conducted in refineries, does not succeed except on sugars which have been prepared by the vacuum pan; hence in countries where open pan-boiling is practised, the process of claying *with clay* is still followed. It does not often happen that one liquoring suffices for the purification of a sugar-cone; almost in every case two liquorings are necessary, sometimes three, but seldom more. The progress of the operation is ascertained from time to time by knocking out a loaf belonging to a lot under treatment, and



BOTTOMING TROWEL.

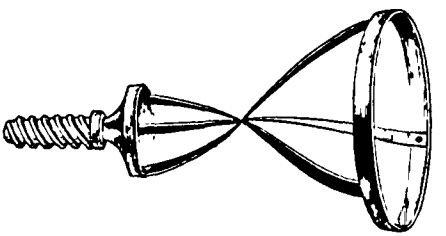
observing the character of percolation. If the crystallised mass be good in quality, the process of clearing is defined by a sharply impressed line. If, however, the boiling have been badly conducted, or the sugar were naturally of bad quality, then the clearing takes place irregularly.

A sugar-cone may be known to have become free from coloured syrup, technically "neat," by the appearance of the fluid which drops from the perforated apex

FACING MACHINE.

of the mould. Toward the close of the percolation the sugar-cones are loosened in their moulds by striking

each of the latter in succession on a solid wooden block. When percolation has altogether ceased, the faces of



CONICAL CUTTER FOR NOSING MACHINE.

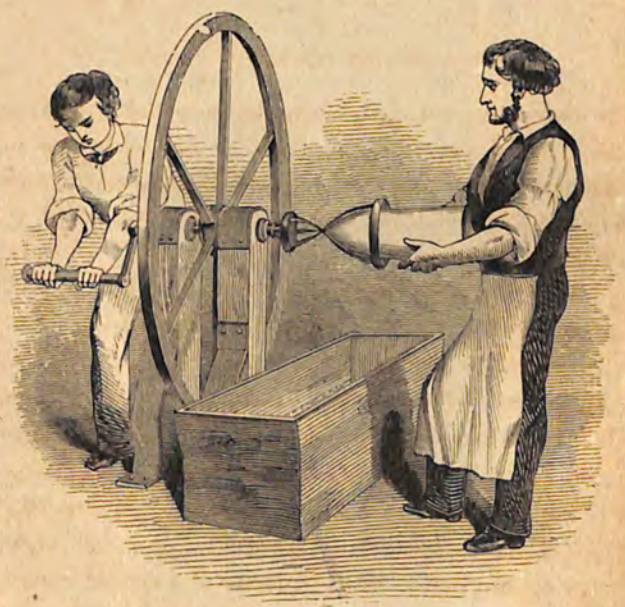
the cones are trimmed, either by means of a rotating blade, called the *facing machine*, or the triangular instrument already described—all the loose, ill aggregated, imperfectly crystallised sugar there existing, being cut away.

The cones are now finally knocked out of their moulds, and subjected to further treatment, its nature depending on the size or character of the sugar-cones themselves. Those above the weight of sixteen pounds, and which are known in commercial language as *lumps* and *titlers*, have simply their apices truncated by means of a knife struck with a mallet. Sugar-loaves, however, properly so called, retain their apices, or rather have new apices given to them, by means of a conical cutter attached to a sort of turning lathe. This instrument is known in sugar refineries, under the technical name of the "*nosing machine.*"

The next step, whether for loaves, lumps, or titlers,

consists in enveloping them with paper. The papered cones are then deposited on trellised shelves, in a room called the *stove*, heated by steam-pipes to the temperature of about 130° F.

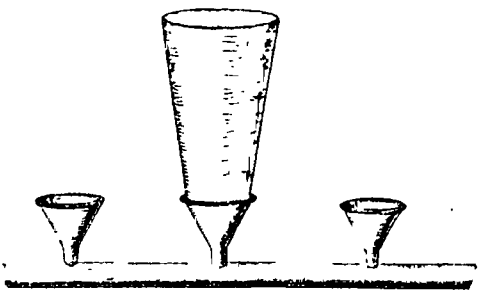
Thus have we brought the refining operation, as usually conducted, to a close. Several modifications of the process, as already described, are adopted; and many contrivances, some of them ingenious, I have altogether



THE NOSING MACHINE.

passed over. One is so ingenious, that it ought not to be omitted. It is the process of facilitating drainage

by means of *suction.* The operation is conducted in this manner :—Connected with the air-pump is a hori-



HORIZONTAL TUBE AND CONICAL CAPS FOR FACILITATING DRAINAGE.

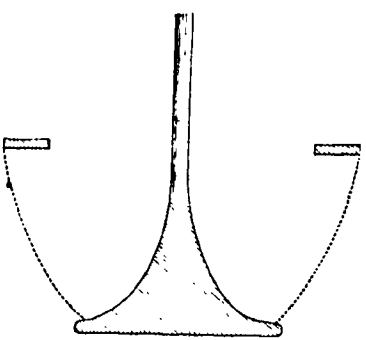
zontal tube, furnished with conical caps vertically placed, into which the apex of a loaf-mould may be fixed air-tight, and subjected to exhaustion.

Neither ought I to forget the very ingenious process of facilitating drainage by *centrifugal agency,* a process which has been successfully applied in Belgium and France to the manufacture of sugar from beet-root; and which has been lately extended to many of our own refineries. Whatever difference of opinion there may be as to the excellence of the centrifugal system in its latter application, there can be none as to its ingenuity and beauty.

The first idea of centrifugal machines for sugar purification, called *turbines* by the French, seems to have been taken from dyeing and bleaching establishments, wherein machines for the drying textile fabrics by cen-

trifugal force were long in operation, before any one thought of employing them in sugar-works. I believe it is impossible to indicate to whom the merit of applying them in their first capacity belongs, or to ascertain the country even of their first introducer into sugar-works. In the year 1850, the employment of centrifugal machines in the manufacture of sugar involved, in England alone, no less than thirty-six patents.

The turbine may be described as a wire gauze cup, strongly fortified with wire and bars, mounted on a ver-



SECTION OF TURBINE.

tical pivot, and supplied with the means of revolving at velocities even so high as 1,500 revolutions per minute. It is very curious to witness the operation of one of these turbines on a mass of crystalline sugar in admixture with syrup. About fifty-six pounds weight of the latter being poured in, and the machine caused to rotate, the thick magma of sugar and water, gradually extends up

to the edge of the turbine, in a crust some three inches in thickness; beyond this edge it cannot extend, being there retained by a flat horizontal band of metal. The syrup yet uncrystallised, or incapable of crystallisation, flies off in a continual shower against the sides of the box in which the turbine revolves, and in the course of ten or fifteen minutes, the sugar becomes quite dry, and may be removed. Nor does the efficiency of the turbine stop here. Not only may a mixture of sugar and syrup be freed from the latter, but if desired, the remaining sugar may be washed, or liquored, simply pouring some liquor into the turbine whilst it is yet in motion. The same centrifugal motion which causes the evolution of syrup, also causes the liquor to force its way through the layer of sugar. It is evident, that the rotatory principle, as embodied in the turbine just described, is only applicable to sugar in the condition of disintegrated grains, technically known in commerce under the appellation of pieces, and crushed lump. By an ingenious modification of this turbine, however, it has been also adapted in France and Belgium to the manufacture of loaves.

Having given an outline of the process of sugar manufacture as ordinarily conducted, involving the use of lime, blood, and animal charcoal, it remains for me to offer a few remarks on the process lately introduced by Dr. Scoffern, and which has been productive of much comment, not only in private circles, but also by the government. In every case of sugar manufacture,

one object is paramount—*the removal of impurities.* Perhaps no agent is so effectual in accomplishing this, as the subacetate of lead. Chemists have long been aware of this fact, but they could not separate the excess of subacetate of lead, which is poisonous, without injuring the sugar at the same time. Dr. Scoffern accomplished this result, ingeniously and effectively, by means of sulphurous acid gas, which being transmitted through the leaded sugar solution by means of a forcing pump, every portion of lead is removed. I do not appear here as the advocate of Dr. Scoffern's process, or any other; but it is only just to say, that the opinion I gave two years ago in favour of the efficiency of this process, and of its absolute safety, when carefully and skilfully conducted, has been fully borne out by my experience since that time. I believe the means of extracting the last portions of lead by Dr. Scoffern's process are infallible, and that they involve no greater amount of difficulty, or skill, than may be commanded by every sugar manufacturer, who chooses to devote adequate attention to the subject.

PRACTICAL INSTRUCTIONS FOR USING THE VACUUM-PAN.

EVER since the discovery of the vacuum-pan, the method of using it has been veiled in secrecy. I have had communication at different periods with the greater number of metropolitan, several country refiners, and with a still greater number abroad. Of British refiners, I only met with one principal who had a sufficient knowledge of the vacuum-pan to conduct an operation of boiling. By far the greater number are so unacquainted with the machine, that they could not check the work of the boiler by reference to theoretical knowledge of the philosophic principles on which the action of the vacuum-pan depends. These remarks do not apply to continental refiners, most of whom possess not merely a theoretical, but a practical acquaintance with the vacuum-pan, and could use it in the absence of a boiler.

It is strange that the community of "boilers"—most of them Germans—who are engaged in English refineries, have managed so long to turn their secret to profitable account. As it is, they succeed in creating the impression amongst their subordinates, that any attempt to work the vacuum-pan without previously making an honorarium of at least ten guineas to the boiler, would be futile.

Ten guineas, I believe, is the *usual sum* paid by a

pan-man (who is a sort of boiler's assistant) before he is allowed to take a proof, and shown how to "*put in the grain*," this being the technical expression amongst sugar-boilers for the generation of crystals. Nevertheless, it happens that the pan-man may possibly have conducted thousands of boilings, each through nine-tenths of its total duration; for the boiler usually directs his attention to no more than two phases of the evaporative operation; he stands by, frequently taking proofs, until the first crystals have appeared (putting in the grain), and being called by his subordinate when the pan has got its full charge, he determines when the proper degree of evaporation has been arrived at—consequently, when the steam should be cut off, and the evaporated liquor allowed to escape from the vacuum-pan by opening the valve.

Occasionally, but far more rarely than prudence should dictate, a stranger—perhaps a colonist—presents himself at a refinery for the purpose of learning the secret. Then the prescriptive fee of ten guineas is departed from, and the student is charged a sum ridiculously disproportioned to the amount of information conveyed.

The vacuum-pan, nevertheless, is an instrument which depends upon a combination of chemical and mechanical principles. Its particular use cannot be learned by mere directions, nevertheless directions can be so given that any person of ordinary capacity, by following them, may become, after conducting a few operations, a good practical boiler.

In the first place, then, the student should consider the nature and objects of the vacuum-pan. It is a copper shell, composed of two hemispheroids, the lower one imbedded in a steam jacket, the upper one not so imbedded. In addition to the steam jacket external to the lower hemispheroid, there is internal to the same, and coiling spirally within, a copper steam-tube, technically called a worm.

In the lower hemispheroid of the vacuum-pan, there is only one opening. This is for the purpose of letting off the liquor when sufficiently evaporated. It is closed by means of a valve or door, opening downwards, and acted upon by a lever. Its edges are ground perfectly air-tight against a rim, and the door should be capable of closing accurately by means of oiled contact alone. Nevertheless, in practice, and with pans that have been some time in use, this accurate contact is not to be depended upon; hence it is a safe plan, and one usually followed, to stop all chance of air leakage by pouring a little syrup into a circular depression, which surrounds the ground edge of the door valve, and supplied with this intention. A similar remark is applicable to the man-hole cover, and its corresponding rim, to be described hereafter in connection with the upper hemispheriod. These large ground surfaces, in consequence of their great extent, scarcely admit of any other treatment in practice, but it should not by any means be extended to the small ground joints corresponding with the barometer and thermometer. There can be no

excuse for employing, for the purpose of rendering these air-tight, any other liquid than oil, sparingly applied.

I will assume the operator about to try the efficiency of a new vacuum-pan, never yet used, and will trace the operation of boiling a charge of sugar to its close. The first points to be ascertained are the condition of the air-pump, and the state of the pan as regards tightness. The operator commences first by setting in action the air-pump; he then turns on a small amount of water into the condenser, for the purpose of moistening the valves of the pump, without which care the result of pumping will be inefficient, the so-called air-pump not being intended to pump air, but a mixture of air and water. These directions having been attended to the barometer gauge is to be carefully regarded. If the vacuum could be rendered perfect (which it cannot), the mercury should stand at the same level in both legs of the barometer gauge. In proportion as such an equality of level is reached, or departed from, so will the instrument be in good or bad order. If the mercury refuse to stand, but rise and fall fitfully with every beat and counterbeat of the piston, then there will be somewhere a leak. When such a leak depends on a natural imperfection of the vacuum-pan, and not on a casualty such as the interposition of a grain of sand, or other foreign body, in either of the ground joints, then its discovery belongs rather to the engineer than the manufacturer; nevertheless, for the guidance of colonists and

others, who may chance to have a vacuum-pan, and no engineer, a few remarks may properly be given. To determine the exact ground surface to which the leakage is due, it will generally suffice to apply the ear to each in succession, when generally the hissing sound occasioned by the rushing in of atmospheric air will be sufficiently indicative of the leakage. Occasionally other plans must be had recourse to, the most generally eligible amongst which consists in pouring oil or water externally on the ground joint, and noticing whether it remains there, or whether it be forced inward by reason of atmospheric pressure. Should both these means fail to indicate the locality of the mischief, then each joint must be examined in the following manner; indeed the operation now to be described has to be performed even though the leak have been already referred to one specific ground surface. In the latter case, for the purpose of showing the exact point of imperfection on that surface, I will suppose the ground bearings of the man-hole to be examined; for which purpose, the ground surfaces are to be well oiled, then the oil wiped off, and the surfaces finally dried by means of a piece of rag, or a little cotton waste. A thin paste is now to be made of vermillion and oil, or red lead and oil, a portion of either of which is to be smeared either on the ground surface of the cover, or on the ground surface of the bearing, but not on both. The cover is now to be placed *in situ*, and revolved under pressure in such a manner that every portion of its ground surface may be

brought into contact successively with every part of the bearing. The rationale of the treatment with red pigment will now be obvious. If any inequality of bearing exist, such will be evidenced by interrupted spaces, over portions of which the red pigment has become attached, whilst other portions remain uncovered. It is evident that if the ground surfaces had been perfectly accurate, the imprint of red pigment would have been equally impressed. It is evident, moreover, that the smeared portions of the ground surface will be those requiring to be lowered in order that the joint shall be rendered accurate. This can be, and indeed is, accomplished by careful filing and scraping. A far shorter process, however, suffices for those small tap-like joints which belong to the barometer-gauge, and the thermometer: should either of these joints be imperfect, they may be rendered accurate by means of grinding—a little fine emery and oil being used for that purpose. The operation is conducted by smearing the tap-like portion of the ground joint with the oil and emery, then rotating the latter in its sheath, until the joint has been rendered perfect, which may be ascertained by means of the red pigment. I will now suppose the pan to be proved in good order, so far as relates to external apertures; the next point to be investigated is, whether it be tight as regards steam. The act of turning on steam is one that demands a few remarks relative to precautions necessary to be taken in order to guard against rupture or explosion. In the first place, it may be laid

down as a general rule, that a steam-tap, with whatever vessel communicating, should never be turned suddenly and at once, but gradually. Neglect of this precaution often leads to dangerous accidents, and always exposes the pipes, joints, and vessels immediately concerned, to risk of fracture. There is another precaution to be observed in the operation of letting steam into the jacket or worm of a vacuum-pan, or, indeed, into any closed vessel. Simultaneously with the entrance of the steam, the air contained in such vessel must be allowed to escape through a tap supplied with this object. The rationale of this operation will be evident on slight consideration. It is this—the steam (always under pressure) enters the closed air-vessel, and disposing of a portion of its latent heat, without itself getting less hot, heats, and consequently expands the air contained in the vessel. Hence the latter has to restrain the pressure, not of steam alone, but of a mixture of steam and air. Consequently, before turning steam on to the vacuum-pan, or any vessel constructed on a similar principle, it is always necessary to previously open an air-tap, for the purpose of allowing air to escape. The tap should be retained open until steam is observed to issue violently from it: it should then be closed. The practice of retaining it a little open during the whole operation of boiling, as is followed by some sugar boilers, is totally unnecessary.

It now remains to treat of the pressure of steam best adapted for working the vacuum-pan. In the

greater number of sugar houses, this pressure is not allowed to exceed ten pounds to the inch; it may be that a pressure still lower, say seven or eight pounds to the inch, is still better; at any rate, steam of above ten pounds to the inch should not be employed—firstly, because its heating power (under the circumstances of its employment) is not so great as that of steam at a lower pressure; secondly, because of the dangerous strain to which high-pressure steam subjects the apparatus.

In stating that high-pressure steam has not so great a heating power as low-pressure steam, the remark must be limited to the condition of heating a fluid by means of a steam-warmed jacket or coils. If a fluid be heated by injecting steam into and through it, then high-pressure steam, weight for weight, is the more powerful.

Inasmuch as the greater number of refineries possess high-pressure engines, although low-pressure steam is necessary for working the vacuum-pan, an intermediate receptacle, termed the *expansion vessel*, is required. It consists of a cylinder of metal, to which a valve is attached, weighted to the degree of maximum pressure which the contained steam is allowed to reach, and which pressure, once exceeded, the valve opens, and, facilitating the escape of a portion of steam, maintains the desired equalisation.

In thus describing the steam portion of the vacuum-pan, one part of the apparatus has been purposely omitted until this time.

Proceeding with our investigation of the successive

phases of action which develop themselves on admitting steam into the jacket and copper worm of a vacuum-pan, we shall presently find the necessity of an adjunct, as yet undescribed. The steam portions and appendages of the vacuum-pan being only heated to the temperature of the surrounding atmosphere anterior to the admission of steam, it follows that a certain amount of steam will be condensed into water by the operation of cooling. It is certain, moreover, that such cooling agency will be always in operation; therefore, except some provision were made for removing the water thus resulting from condensation of steam, the jacket and worm would soon be rendered inoperative. Such provision is made by an instrument termed the *condense box*. To describe the mechanism of this apparatus is unnecessary, seeing that, its principle being enunciated, a slight examination of the mechanism of the apparatus will show in what manner the conditions are applied to practice. The "condense box" must necessarily be fixed on a lower level than that of the vacuum-pan, from which it is usually some considerable distance removed.

Let us now return to an examination of the pan itself. We have already determined that those portions of it, not having immediate reference to steam, are tight, and trustworthy; it remains, therefore, to examine the condition of the steam jacket and coil. For this purpose, the steam being laid on with all the precautions already detailed, the operator places a strong light near the

lens orifice, and looks into the pan through the sight-hole opposite the former; or, turning off the flow of water in the condenser*, stopping the air-pump, and removing the man-hole door, the observer may stand on the rim of the pan and look through the man-hole. It is possible to conceive a case of steam leakage, under the aid of a vacuum, ceasing to be a leakage when the vacuum is removed; such a case, however, is so exceedingly improbable, that the examination of a pan, as to steam worthiness, through the man-hole, may be regarded as perfectly reliable; indeed, on account of the larger and more ready sphere of vision thus commanded, the plan is preferable to an examination of a pan, as to this point, through the sight-hole.

Any defect as regards steam-worthiness can easily be observed, and its locality no less easily determined, by noticing the exact point at which the steam escapes. The escape may be either internal or external. It may be from a crack in the substance of the steam jacket, or from a defective joint. If the former, the defect is fatal—the jacket must be replaced by another; if in a joint, it may be remedied by unscrewing the latter, and repacking it with tow and a mixture of red and white lead; if in the worm, the latter must be removed, and the defective part made good by brazing. Wherever a steam leak exists, and from whatever cause, it is always to be regarded as a serious impediment; but, next to a crack in the jacket, the existence of which renders an explosion

* Not to be confounded with the *condense box.*

imminent, a defective worm is the most grave condition. The consequence of the latter is, that a charge of sugar under process of boiling continually undergoes a joint operation of dilution and evaporation, thus, *pro tanto*, destroying the specific advantages of the vacuum-pan.

Let us now assume the vacuum-pan to have been determined perfectly efficient in every respect, and the process of boiling to be commenced. The operator begins by first setting in motion the air-pump, then turning on the condensing jets, opening the air-tap in the vacuum-pan jacket, and gradually turning on the steam. He now begins to charge the pan, keeping correct account, measure by measure, of all the liquor which goes in. Of measures there are two kinds—one kind open, the other closed. The latter is most frequently employed, possessing the advantage of drawing its supply of liquor from a lower floor than that on which the pan is placed, such being in most refineries the place of greatest eligibility for the liquor cistern. It need scarcely be indicated, that closed measures, as they are called, communicate by means of a tube with the liquor cistern, through which the liquor ascends into the measure, by the force of the suction exercised by the pan itself.

The total number of measures of liquor, which a vacuum-pan is capable of working, being known, about one-third of that total quantity should be allowed to enter, and should be submitted to the full force of the pan—that is to say, the act of ebullition may be carried to any extent short of that which would result in boil-

ing over. At this stage no harm can accrue from carrying on evaporation with rapidity; and, besides other advantages, a considerable saving in time will be gained. It is not to weak non-concentrated liquors that even the greatest evaporative power commanded by the vacuum-pan can be injurious, but to the concentrated result of evaporation hereafter to be described.

If the liquor be of good quality, the boiler has very little to be solicitous about at this stage of the operation, further than observing that every function of the pan is being well performed. He need take no account of the liquor within. One function of great importance in itself, and the consideration of which, boilers too frequently neglect, is *condensation*. If this be not adequately performed, much of the efficiency of the vacuum-pan is lost. In order that condensation may exercise its maximum effect without over-balancing the exhaustive action of the pump on the one hand, or permitting a portion of steam to remain uncondensed on the other, some care is necessary. The condenser should never feel hot; therefore, if such elevation of temperature be recognised on applying the hand externally, more water should be turned on. If, notwithstanding the supply of the maximum amount of water compatible with circumstances presently to be described, the condenser is still hot, the steam power of the pan must be diminished by a partial turning of the tap. The circumstances acting as a limit to the quantity of water capable of being brought into action by any given con-

denser are chiefly—(1.) size of the condenser; (2.) number and size of jets communicating with it; (3.) power of the air-pump. If, from any combination of circumstances, the condenser be overloaded with water, the latter, instead of being removed altogether by the pump, flows back into the vacuum-pan, and, mingling with the sugar solution, proves very detrimental to the ultimate result.

From a consideration of the principles on which the condenser of a vacuum-pan is based, it follows, that in proportion as the fluid to be evaporated is less dense, or more watery, so will the amount to be removed by evaporation be greater; hence the size and power of the condenser may have immediate reference to the purpose for which the pan is intended. A power of condensation amply sufficient for the necessities of a vacuum-pan, when employed in concentrating the dense liquors of a refinery, may prove totally inadequate to the altered necessities of colonial manufacture, where the juice to be evaporated is more watery. On one occasion I conducted the evaporation of cane juice to crystallised sugar altogether by means of a vacuum-pan. The condenser was one of great power, and the command of water unlimited; had it not been for these circumstances, the operation could not have been carried on to a successful termination.

Returning now to the liquor under operation in the pan, it will be time to examine, by taking a proof, to what extent the evaporation has been pushed. The

original quantity of liquor in the pan is supposed to have been a third of the pan's total charge; its density is supposed to have been about 27° or 28°B.; its quality the best. Under these circumstances, supposing the evaporative operation to have been briskly carried on for about half an hour, crystals should begin to manifest themselves. The only certain way of recognising their presence, judging of their size, and their general qualities, consists in taking a proof; full directions for accomplishing which will be given presently. There are other indications, however, of the formation of crystals, which the operator should learn to appreciate. One of these is the peculiar crackling sound, like that of salt thrown on the fire, recognisable so soon as crystals have formed, on applying the ear to the side of the vacuum-pan. It appears to depend on an alteration in boiling of the solution of sugar in which crystals have begun to form. Anterior to this period it is viscous—*tenacious;* subsequently to the formation of the crystals, the physical character of the liquid alters. It is more thin, less tenacious, and the angular crystalline particles which it contains exercise a physical effect on the operation of boiling, which now takes place with greater rapidity than before, and with a series of sharp, but minute explosions. This peculiar characteristic, which may be designated as *crepitation*, is especially noticeable when a solution of pure cane sugar is operated upon. The boiler should lose no opportunity of making himself familiar with so important an indication.

Another sign of the formation of crystals in the liquid undergoing evaporation, consists in what is technically called "*the flash.*" This is a sort of sparkling recognisable on looking down upon the charge through the sight-hole. The flash is due to the operation of certain reflective and refractive effects of the crystals on the beam of light shining down upon them from the lamp.

Taking the proof.—This is the great secret of vacuum-boiling, making known to the operator the exact condition of things inside. It is accomplished by means of a very ingenious contrivance, termed the "*proof-stick,*" the further description of which may be omitted here, seeing that these remarks are intended for practical men, who have access to a vacuum-pan, which, if carefully examined in all its parts, the nature of the proof-stick will be evident.

It will facilitate the comprehension of this part of the subject if we treat separately of the method of getting out a proof, and the examination of this proof when got out. The operation of getting out a proof requires four distinct manipulative acts, all of which it is necessary for the practical sugar-boiler to comprehend thoroughly. They may be described as:—

(1.) Insertion, or position 1.
(2.) Half-turn upwards to the left, or position 2.
(3.) Half-turn downwards, ending at position 1.
(4.) Withdrawal, position 1 being maintained for about the first six inches, then position 2.

Consequently it appears that, the proof-stick having

been properly inserted, the remaining portion of the manipulations is a matter of simplicity. Now, as regards this insertion, it must always be remembered, to thrust down the proof-stick with the scooped portion of its extremity looking *downwards*. Of course there can arise no difficulty in respect of this, but frequently it happens, that after the proof-stick has been allowed to remain some time in the sheath, the operator forgets in which direction this scooped portion of the extremity lies, whether upwards or downwards; hence, an additional means of discrimination is necessary. This is provided by the maker in the following manner. The handle of every proof-stick is marked with a little round excavation, on the same side as the scoop, at the extremity—whence it follows, that whether the proof-stick be within or without the sheath, the exact position of its scooped extremity can be readily determined.

Returning now to the operation of examining the proof withdrawn, the process is this:—Near to the operator is placed a light—a gas light, on account of its brilliancy, being preferable to all others. Usually this light is placed in a box, the sides of which are painted dark, though this arrangement is not indispensable. The object of the light is to enable the operator to examine the condition of the proof by the transmission through it of luminous rays, by which means, if any crystals are present, they can be readily seen long before they are large enough to be felt. The means adopted for transmitting luminous rays through the

evaporated material, consist in throwing it out from the scooped end of the proof-stick upon the thumb of the left hand approaching the fore finger, separating it, and thus extending the material to be examined in the form of a sheet, which being held between the source of light and the eye, the presence or absence of crystals is readily determined. Supposing the operator to be satisfied that crystals, technically called grains, really exist, he has nothing more to concern himself about just at present, further than to take care that the evaporative operation go steadily on; under which treatment the crystals will soon be found to increase in size and in number; to become tangible as well as visible, feeling between the fingers like particles of sand, which, in proportion as they are large and hard, in such proportion are they better,—at least according to English commercial notions. On the continent, however, the production of small grained sugar is aimed at, and indeed whiteness, *cæteris paribus*, is in direct proportion to smallness of crystal.

At this stage of the operation the practice of boiling differs in the hands of various operators—as indeed it must, according to the quality of material exposed to the evaporative action, and the exact condition of staple required. As a general rule, however, it is proper to carry the evaporative process to such a pitch, that a proof can barely be attained on account of the thickness of material in the pan. When this state is arrived at, then it is time to increase the amount of material by turning on a

flow of liquor from the measure into the pan. There are two distinct plans of accomplishing this, either by gushes, or by a process of gradual infusion. The latter is in theory most philosophic—it is that most generally had recourse to by intelligent sugar boilers—and I have no hesitation in designating it the better plan. In practice, it is no less easy than in theory comprehensible, consisting in so arranging the flow of liquid that the amount of liquor permitted to ooze into the pan may be just proportionate to the force of evaporation. If it be less, then the contents of the pan will become too thick; if it be more, then, supposing the operation of evaporation to have been continued sufficiently long, it is evident that the crystals already formed will become dissolved. This latter is one of the most unfavourable state of things which can occur, but it may always be prevented by attention on the part of the boiler, who, by means of frequently taking proofs, can always make himself acquainted with the exact condition of his charge.

When the last portion of liquor is already in the measure, and consequently the operation of boiling almost finished, the boiler must pay great attention to his charge. The quality of his resulting sugar loaves will in great measure depend upon his causing the operation of boiling to cease at exactly the proper instant of time; a few seconds more or less making great practical variations in the results. Nothing but practice—very extended practice—combined with great intelligence, can supply the full information required; nevertheless,

by due attention to theory and general principles, the errors of boiling may be restricted within the range of comparatively narrow limits. Perhaps the following general directions for concluding the operation of boiling are the best, though I am aware that considerable manipulative discrepancies exist in the practice of different operators. Whether the system of feeding the vacuum-pan by sudden gushes or gradual infusion have been adopted, it is always a safe plan for the boiler to adopt the former, as concerns the last measure of liquor. With whatever degree of care the turn of the liquor-tap may have been adjusted, it will be generally impossible to arrange it precisely at that point conducive to the best final result. For instance, at the point when all the liquor save the last measureful has been turned into the pan, and a proof being taken, the operator probably will find that the result is either a little too thin (free), or a little too thick (stiff). Such may happen to charges under the care of even the most experienced boilers. Where the system of gradual infusion is allowed to proceed, this undue stiffness or thinness would continue to the end of the operation; whereas, by taking the last measureful of liquor under his immediate control, the boiler has it in his power to modify this state of things, and bring the evaporative process to the condition finally required. With regard to the exact condition of stiffness at which the operation should be concluded, and the contents of the pan turned off into the heater, there is a considerable difference of practice. Supposing

the material to be of the best quality, the operator may be told, as a general rule, to boil up to the degree of thickness at which a proof can barely be taken. I have indeed seen admirable results produced from the contents of a vacuum-pan boiled so very stiff, that not only could a proof no longer be taken, but the material was obliged to be forced out of the pan by a pole inserted through the man-hole. This material, however, was the result of liquor, which had been purified by means of lead. Sugars defecated by lime and bullock's blood in the old-fashioned manner, contain such an amount of glutinous adhesive matter, that an evaporation carried to the extent described would have been totally incompatible with the subsequent operations of claying, liquoring, and drainage,—operations, on the successful performance of which, the perfection of the final result depends.

Immediately the evaporative operation has been carried to the farthest extent desired by the boiler, the process should be stopped. First of all, the steam communication is cut off; then the flow of water into the condenser; next the air-pump; next, an air-plug being removed, or a tap being opened (contrivances vary in different pans); air is admitted into the pan; and, finally, the let-off valve being opened, the charge escapes into the heater below. At this period a tap is turned, by means of which a jet of steam is injected into the pan, for the purpose of freeing it from adherent sugar.

We must now leave the vacuum-pan, and devote

some attention to the *heater*, the management of which, although less delicate than that of the pan, is scarcely less important. Indeed, the properties of the heater are by no means so well studied as they are worthy of being. The ordinary routine of sugar houses consists in applying to all results, without reference to primary quality or conditions of boiling, such as stiffness and thinness, one uniform degree of temperature by means of the heater. Such a procedure is contrary no less to the dictates of theory than to the indications of practice. By means of variations in the degree of temperature imparted by the heater, considerable defects of boiling, whether on the side of freeness or stiffness, may be compensated and remedied. This fact will readily occur to the theoretical student of the conditions which the heater is competent to subserve, and the principles upon which its agency is founded. They are these. One condition necessary to insure the perfection of crystals is freedom of motion between the molecules about to crystallise. Now, it happens that the range of temperature most congenial to the crystallisation of sugar molecules, is higher than can be prolonged during the whole period of boiling, without producing destructive effects to a large extent, and the avoidance of which is the chief intention of the vacuum-pan. Hence, the practice has arisen of carrying on the evaporative process at a degree of heat lower than that conducive to the state of most perfect crystallisation, and finally imparting this temperature, for a short time only, by

means of the heater. As a general rule, the contents of a vacuum-pan may be assumed to be turned out at temperatures between 140°F. and 150°F., and supposing the material to be of the best quality, and evaporated to a medium degree of stiffness, the temperature of about 173°F. or 175°F. may be considered that most eligible to be imparted by means of the heater. The most ordinary reflection on the conditions affecting the generation of crystals, will indicate the propriety of imparting a lower degree of temperature to a thin, than to a stiff boil. Were this precept neglected, crystals already formed would become re-dissolved.

Boiling by doubles. Occasionally, when the liquor to be evaporated is of inferior quality, the ordinary conditions of boiling already described are not capable of yielding a sufficient crop of well-defined crystals. Under these circumstances, the operation of boiling by doubles, as it is technically called, is frequently had recourse to. The theory on which it is based reposes upon the fact, that crystalline nuclei being placed, under favourable circumstances, in a liquid containing material of a similar kind dissolved, molecules are not only deposited on the nuclei already existing, but the formation of additional molecules is determined. In the operation of vacuum-pan boiling, this principle is readily applied by retaining a small portion of one charge as a foundation for the next.

Boiling by the thread-proof. The operation of vacuum-pan boiling, as already described, has been con-

ducted on the supposition that crystals are formed during the evaporative operation, and the gradual progress of such boiling has been judged of in reference to the appearance of crystals formed as indicated by the proof. Such a result, however, only applies to liquors which are moderately good. In proportion as the material to be boiled becomes loaded with glucose, and other impurities, so will its tendency to generate crystals during the evaporative act diminish; and in the course of the actual routine of a refinery, many charges will have to be submitted to the action of the pan, which no manipulative skill could succeed in granulating under the operation of boiling; hence the method of judging by proof requires to be varied, seeing that crystals will not exist, for the guidance of the boiler. Recourse must then be had to the indication afforded by the length, brittleness, and some other characteristics, of a string of the proof, formed by bringing a portion of the evaporated mass between the finger and thumb, and separating them. Three distinct phases of manifestation will be rendered evident under this treatment. The string may be formed of the length of two nches or more, and which, after existing for the period of a second or two, breaking midway, each end rapidly, almost suddenly, shortening, returns respectively on the finger and thumb, and becomes lost in the two portions of the original mass. This indication serves to show that the material has not been boiled enough for any final purpose. Supposing the evaporative opera-

tion to be still prosecuted, the thread, after breaking as before, forms a hook at either extremity; which is indicative of the fact, that the evaporative process has been almost carried far enough. The evaporation being still continued, the string breaks as before, but its extremities form little spirals each, something like the spiral of a corkscrew, the thread still retaining its power, though in a diminished degree, of collapsing on the finger and thumb. Beyond this degree of evaporation, the operation should not be carried; if pushed to such an extent that the collapsibility of the thread is lost, the final result will drain with difficulty, or not at all; in other words, the process will have been a failure.

This operation is one in vacuum boiling of such great importance, and the neglect of it will so completely destroy the efficiency of the proof apparatus, that for all practical purposes the latter might as well not have existed. Nothing but the most scrupulous attention to cleanliness will maintain it in good working condition, to say nothing of the chances of accident to the apparatus, resulting from attempts to wrench out the proof-stick, when it has become firmly set in its sheath by means of consolidated sugar.

The cleansing of the proof apparatus consists of two acts—the cleansing of the proof-stick, and the cleansing of its sheath. I shall describe both in detail, commencing with the former. The proof-stick having been removed, and the proof examined, the operator, by means of a bit of chip, clears out the proof hollow; he

then plunges the instrument into a pail of water, withdraws it, and wipes it dry. Finally, he oils slightly the two ground or bearing portions of the instrument, namely, the ground ring immediately contiguous to the handle, and the extreme further end. These operations being performed, the proof-stick may be regarded as cleansed, and ready to be employed in taking another proof. The operation of cleansing the proof-sheath is accomplished by sponging—that is to say, a little piece of sponge, or cotton waste, or soft rag, being firmly attached to the extremity of a rod, is moistened with water, plunged down into the extremity of the sheath, rotated several turns, finally withdrawn, washed, and the operation repeated as often as may be necessary, until the cleansing has been accomplished, when, finally, the external ground socket of the proof-sheath is slightly moistened with oil. In conducting the operation of cleansing the proof-sheath, two special points present themselves for remembrance. The rag, cotton waste, sponge, or other cleansing material, attached to the extremity of the rod already described, must be very firmly attached, otherwise there will be great danger of its remaining in the proof-sheath. Should this ever occur, the soft material must be removed at once, which can be best effected by the screw end of a gun ramrod. The second especial point for remembrance is this:—The sheath, although it must be perfectly clean, should never be allowed to retain any considerable portion of the water wherewith it may have been washed—that is

to say, although it is a good plan to begin operations by thoroughly saturating the sponge end of the cleansing stick with water, yet this water having served its purpose, should be finally removed by insertion, withdrawal, and squeezing of the sponge. The propriety of this care will be evident on considering that the operator judges of the progress of his boiling process mainly by the consistency of his proof. In proportion as the latter is thick or thin, so is it inferred that the evaporative process has advanced or been retarded; but if the water due to the cleansing sponge be not accurately withdrawn from the proof-sheath, it is evident that a fallacious indication of thinness will be manifested.

TABLE REPRESENTING THE SPECIFIC GRAVITY OF SOLUTIONS OF SUGAR OF VARIOUS STRENGTHS.

Sp. Gr.	Sugar in 100 parts.	Sp. Gr.	Sugar in 100 parts.	Sp. Gr.	Sugar in 100 parts.	Sp. Gr.	Sugar in 100 parts.
1000	·00	1069	·17	1147	·34	1235	·51
1004	·01	1073	·18	1152	·35	1241	·52
1008	·02	1077	·19	1157	·36	1246	·53
1012	·03	1081	·20	1162	·37	1252	·54
1016	·04	1085	·21	1167	·38	1257	·55
1020	·05	1090	·22	1172	·39	1263	·56
1024	·06	1095	·23	1177	·40	1268	·57
1028	·07	1100	·24	1182	·41	1273	·58
1032	·08	1104	·25	1187	·42	1279	·59
1036	·09	1109	·26	1193	·43	1284	·60
1040	·10	1113	·27	1199	·44	1289	·61
1045	·11	1118	·28	1204	·45	1295	·62
1049	·12	1123	·29	1209	·46	1301	·63
1053	·13	1128	·30	1215	·47	1307	·64
1057	·14	1133	·31	1220	·48	1312	·65
1062	·15	1137	·32	1225	·49	1317	·66
1066	·16	1142	·33	1230	·50	1321	·666

TABLE OF THE DENSITY OF SOLUTIONS OF SUGAR ACCORDING TO THE SCALE OF BEAUME.

Degrees of Density.	Sugar in 100 parts.	Degrees of Density.	Sugar in 100 parts.	Degrees of Density.	Sugar in 100 parts.
1	·018	13	·237	25	·462
2	·035	14	·256	26	·481
3	·052	15	·276	27	·500
4	·070	16	·294	28	·521
5	·087	17	·315	29	·541
6	·104	18	·334	30	·560
7	·124	19	·352	31	·580
8	·144	20	·370	32	·601
9	·163	21	·388	33	·622
10	·182	22	·406	34	·644
11	·200	23	·424	35	·666
12	·218	24	·443		

LECTURE VI.

ON WOODY FIBRE.

THE chemistry of *woody fibre* opens a wide and an important field of inquiry. Whether we regard it, according to the popular acceptation of the term, as constituting the material of timber, or whether, extending the definition to its widest chemical limits, we include hemp, flax, cotton, and the vegetable materials of other textile fabrics, the subject involves the description of numerous important arts.

It is my intention to confine myself, during this lecture, to a description of the chemical nature of woody fibre, and to examine the relations it presents to other chemical bodies; to indicate some of the derivative substances capable of being obtained from it; to point out the various destructive changes to which it is naturally prone; and lastly, to explain how these changes may, by chemical treatment, be prevented.

Viewed as to its chemical constitution, woody fibre, or *lignine*, presents analogies to the starch and sugar series. Like them, it differs in ultimate composition from the majority of *animal* principles, in having a *ternary*, not a *quaternary* composition; nitrogen being

altogether absent. The table, however, to which I now direct your attention, will explain its composition, and its chemical relations to starch, &c.

	C=8	H=1	O=6	Equi.
Lignine	24	16	16	288
Cane Sugar (dry) . . .	24	18	18	306
Milk Sugar (dry) . . .	24	19	19	315
Starch (dry)	24	20	20	324
Grape Sugar (dry) . . .	24	21	21	333
Gum (dry)	24	22	22	342

Although the physical aspect of ligneous or woody fibre be exceedingly various, according to the source from which it is obtained, yet, when chemically examined, its composition is found to be invariably the same.

In accepting this statement, care must be taken to guard against a fallacy which presents itself. Although woody fibre be chemically the same from whatever kind of wood derived, yet nothing can be more different than the chemical qualities of various woods. Thus the fir tribe is characterised by the presence of turpentine; the oak tribe by the presence of astringent tanning matter; the maple tribe by the presence of sugar, and so on. Nevertheless, the general proposition of the identity of lignine or woody fibre, from whatever source obtained, is undisturbed. The differences adverted to are merely superadded differences; differences not of substance but

of secretion; woody fibre constituting only the vehicle in which those secretions are contained.

These remarks point to the method by which lignine, or pure woody substance, may be procured by the operator. A convenient portion of fine saw-dust being taken, it is subjected to the action of such a course of solvents as may be adapted to the removal of the associated secretions. Thus the saw-dust is first exhausted by treatment with hot water; it is then subjected to the action of dilute acids, alkalies, alcohol, and ether; in short, to the action of any fluid which may be competent to remove the associated bodies with which it is combined. The residue of such treatment is lignine, or woody fibre.

Although such is the method of obtaining lignine pure, as a chemical specimen, all the ordinary characteristics of the substance may be recognised in a much simpler way. Hemp, flax, and cotton, represent all the leading qualities of lignine—the latter, of lignine almost in the condition of purity. Lignine is an exceedingly insoluble body, as indeed will be anticipated from a consideration of the uses to which it is applied, and of the processes to which it is subjected in the routine of common operations. Thus we do not find that subaqueous piles; and other wooden fabrics similarly placed, are dissolved by prolonged contact of water. Neither do linen and cotton cloths dissolve when washed; nor does *paper*, which is a manufactured form of lignine or woody fibre, dissolve when soaked in water. In the

latter case, the short filaments of woody matter become separated from each other, owing to the penetration of water between them; but, in the proper sense of the term, they do not dissolve.

Lignine, or woody fibre is very combustible. If quite pure, it yields no ashes when burned in contact with oxygen, or atmospheric air; linen, flax, paper, &c., all yield, under the same circumstances, a small amount of ashes, but this is due to impurities which they contain within their substance.

On subjecting lignine to the operation of destructive distillation—that is to say, on heating it strongly in vessels from which air is excluded—one portion of carbon which it contains remains behind in the state of *charcoal*, whilst another portion combines with oxygen and hydrogen, and generates numerous important secondary compounds, amongst which *acetic acid* is the chief. *Vegetable tar* is another of these results, and is in itself a very complex body, holding numerous organic compounds, of which paraffine, eupione, creosote, picamar, and pittacal, are the chief.

Having pointed out the consequences of subjecting woody fibre to the powerful chemical agencies of combustion and destructive distillation, I shall now indicate a few of the more important and more interesting results of slow chemical action upon it, and this will lead us to investigate the properties of that remarkable substance, *gun cotton*; to study the relations between woody fibre, gum, and sugar; and to

investigate the causes of dry-rot and other forms of decay.

Referring to the composition of lignine, as represented by the table (at p. 235), its hydrogen and oxygen will be seen to exist in the proportions necessary for generating water; hence, if water be removed by any agent having a strong affinity for it, carbon would remain. A consideration of this fact furnishes the rationale of the action of strong sulphuric acid on lignine. I here pour upon a quantity of saw-dust some oil of vitriol, and incorporate it, by means of a glass rod, with the mass. Copious fumes are evolved, chiefly of acetic and formic acids, and ultimately a mass of *carbonaceous matter* remains. This result is almost identical with that which ensues when sugar is substituted for saw-dust, and the rationale of the process is the same. This, however, is only *one* kind of agency which oil of vitriol is capable of exercising on woody fibre. By a modification of the process, the lignine may be converted into gum, and the gum into sugar. The conversion of lignine into gum may be effected by adding strong sulphuric acid, as in the preceding experiment; taking care, however, to prevent elevation of temperature, by surrounding the mixture of acid and saw-dust with ice. If this gum be now dissolved in water, and exposed to prolonged ebullition, (from 36 to 48 hours), it will be found converted into glucose, otherwise called grape-sugar.

Nitric acid exerts a very peculiar action on lignine,

more especially lignine in the form of cotton, the result is the celebrated *gun-cotton*, a discovery of Schönbein, of Bâle. The simplest process of making gun-cotton consists in dipping the fibre (which must be perfectly clean) into strong nitric acid, allowing the acid to saturate it thoroughly, then finally removing the cotton fibre, washing until every trace of acid is separated, and drying at a temperature under 100°. Practically, however, it is found desirable to mix a little sulphuric with the nitric acid, for the purpose of strengthening the latter, which it accomplishes by its affinity for water.

Gun-cotton, although still resembling ordinary cotton to the naked eye, feels different, and presents a different aspect when examined microscopically. The rapidity of combustion, and consequent explosive energy of this body, are intermediate between those of gunpowder on the one hand, and chloride and iodide of nitrogen, fulminating gold, silver, and mercury, on the other. When ignited, it burns with a brilliant flash; and, if carefully prepared from pure cotton, it scarcely leaves a residue. At one time, the belief was very general, that gun-cotton would supersede gunpowder. Extended trial, however, instead of bearing out the supposition, has demonstrated the reverse. Gun-cotton has been found inadequate to take the place of gunpowder with advantage in any operation, to the performance of which that agent is applied. Many circumstances conspire to prevent the application of gun-cotton to the purposes of gunnery. Its velocity of combustion is too great for

all fire-arms, save those of strongest make and smallest bore. Its strength is subject to variation, not only from the operation of atmospheric causes, such as the absorption of moisture, but from spontaneous decomposition; the latter agency reducing gun-cotton, after a certain time, to the original condition, or ordinary combustibility, of native cotton. The physical conditions of a fibrous body moreover, are very much opposed to its employment in fire-arms, especially those supplied with the breeching ordinarily known as "*patent*," and which consists of a cavity much smaller than the diameter of the barrel itself, and which is intended to contain the charge. If a chamber or cavity of this kind be not quite filled with the explosive material, the gun is very liable to burst, and such a chamber can only be filled with an agent of the physical constitution of cotton, by the exercise of much care and address. When to these objections, are superadded those of ignition from percussion, or even spontaneously, and the acid fumes (although no smoke) evolved by gun-cotton undergoing combustion, the impossibility of making this curious body a substitute for gunpowder in fire-arms will at once be recognised. Its employment as a blasting agent in mines seemed to promise a greater measure of success. The total freedom of smoke with which it burns, is undoubtedly a great advantage to the miner, who, frequently, under the present system is obliged to cease work until the suffocating fumes and smoke of gunpowder

shall have slowly disappeared. Unfortunately, however, the use of gun-cotton has been discontinued even for this purpose, chiefly on account of the danger attending its manufacture, and its tendency to explode from the operation of slight causes.

The composition of gun-cotton has not been accurately determined, nor are chemists agreed as to the rational formula by which it may be represented. We must therefore rest satisfied with regarding it as a combination of nitric acid, or of nitrous acid, with lignine, or modified lignine, in which the latter performs the part of a base.

Before taking up the subject of *timber*, the cause of its decay, and the methods of arresting that decay, I must slightly advert to two different operations having reference to the effecting of modifications in woody fibre by means of chemical treatment—one being the cottonising process of Claussen, the other the corrugating process of Mercer.

On account of the difficulties of working flax in those forms of machinery employed in the manufacture of cotton, M. Claussen converts flax, by a chemical process, into a state something like that of cotton. This he accomplishes by first steeping the flax in a lixivium of carbonated alkali, and subsequently in a weak acid. Now the combined agencies of these two menstrua are as follow: No sooner does the acid come in contact with the carbonated alkali, previously absorbed by the cotton fibre, than carbonic acid is liberated; which gas, exer-

cising a pressure, bursts the filaments of the flax asunder, and reduces the material to a physical condition something like that of cotton.

Mercer's corrugating process has for its object the strengthening of cotton tissues by corrugation of their fibres: this he accomplishes by the action of caustic alkaline leys, which deposit their alkali in the state of chemical union with the cotton cloth, swelling, and at the same time corrugating its tissue; whilst the capacity of that tissue for the reception of colours is simultaneously increased.

It is not a little remarkable that the corrugating process should have remained for Mr. Mercer to discover. Ever since the first establishment of the cotton manufacture, a solution of soda has been employed in one stage of the operation of bleaching; but the solution, when employed with this object in view, is employed hot, and this circumstance accounts for the long period during which the facts observed by Mr. Mercer, and incorporated into his new process, remained undiscovered.

If cotton be submitted to the action of a hot solution of soda, no combination of the alkali with the cotton fibre takes place, but a mere bleaching action results, chiefly dependent on the removal of coloured resinous matter. If, however, the same cotton fibre be subjected to the action of cold soda solution, a very peculiar result ensues. Supposing the cotton fabric to be acted upon be employed in the manner of a filter, and the alkaline solution poured through it, then, if the layers of cotton

be sufficiently numerous, the whole of the alkali contained in the solution employed will be removed, and retained in combination with the fabric, imparting to it the peculiar corrugated appearance so characteristic of this combination. The combination, however, is not permanent: no sooner is the tissue exposed to the action of boiling water, than the whole of the soda is expelled. The cotton, however, does not return to its original state—for every equivalent of soda expelled, an equivalent of water has been taken into combination, and this combination is permanent.

The two direct advantages of this corrugating process have been already stated. The texture is rendered thicker, and its capability of receiving colour is heightened. There are also indirect advantages, of no small importance, consequent on this beautiful operation. Thus the manufacturer acquires a new means of forming patterns on a cotton texture; for if one part of such texture be covered with a protective varnish or resist, and the other parts be exposed to the corrugating influence, then it is evident a pattern will result.

Again, by exposing mixed fabrics, containing cotton as one of their constituents, and wool, to this agency, the cotton alone suffering corrugation, it is evident there would result an effect only requiring the application of a little intelligence to develop into marketable value.

We have already seen that *gum* and *sugar* (the grape variety) may be obtained by the action of sulphuric acid on woody fibre. *Bread* has also been

made of this substance; indeed, before me is a specimen of such bread imported from Sweden. Seeing the close relation between the composition of starch and lignine, the conversion of the latter into bread does not appear so remarkable. I cannot say much, however, in favour of this bread; indeed, the quality of all such specimens, from a similar source, which have come under my notice, has been very poor.

We now arrive at the consideration of woody fibre, or lignine, in its most prominent form, as constituting the structure of *timber;* the importance of which, as a building material, it cannot be necessary to indicate. It is now, when considering this point of the subject, that the *slow chemical changes* to which woody fibre is subject become a matter of deep practical interest, as originating many amongst the various species of *rot*, or *decay*, to which timber, under certain circumstances, is prone.

The varieties of slow disintegration which timber, under different conditions, may assume, are numerous and diversified; but practical writers usually divide them into two classes—the wet rot, and the dry. The former depends for the most part, if not exclusively, on a real chemical decomposition, referable to the combined agency of air and moisture, exercised at certain temperatures; the latter is chiefly, if not entirely, attributable to the growth of certain fungi—more particularly the *Polyporus destructor*, *Merelinus lachrymans*, and others which are of a more simple nature, all belonging to the genus *Sporotrichum*.

Now the decomposition of timber, from any cause, may be impeded, and, in the case of dry-rot, may be altogether prevented, by imbuing the woody fibres with certain mineral solutions. Nor is this the only advantage attendant upon the use of such solutions: all of them which have been suggested, or brought into operation, by investigators, at different times, possess the quality of *diminishing the inflammability* of such timber as may be imbued with them.

Mr. Kyan was the first who practically carried out this idea of imbuing the substance of timber with a metallic solution. The preservative material employed by this gentleman was *corrosive sublimate,* the bichloride of mercury, and when merely considered in relation to its preservative effect, corrosive sublimate answers the purpose desired. There are various objections, however, to its employment. In the first place, it is an expensive material; in the second place, it is a poisonous, and a volatile material. Not only are the workmen who use it exposed to danger from its absorption, but there is reason to fear that living in continuous proximity with Kyanised timbers,—as, for instance, on ship-board, may be prejudical to the health of a crew thus situated. In short, although the preservative effects of Kyanising are complete, the objections to this mode of preservation were so numerous, that another preservative solution was a desideratum.

This desideratum has been fully attained by the invention of Sir William Burnett, who, instead of bi-

chloride of mercury, employs the less expensive, more fixed, and equally efficacious salt, *chloride of zinc*,—a material which, so far from rendering timber injurious to health, possesses the great collateral advantage of being a disinfecting agent; for which purpose it is now indeed commonly employed. Before me I have duplicate specimens of wood, canvass, and other ligneous substances. One portion of each duplicate has been exposed to the preservative effect of chloride of zinc, the other not; and both have been subjected to the same conditions. The difference in all these cases is evident. In the unpreserved portion, wet and dry-rot, and other destructive changes, have committed sad ravages; in the other, the material retains all its original soundness.

With these striking instances before me, it does seem extraordinary, not to use a stronger term, that architects, and all who have to employ wood for purposes involving duration, do not avail themselves of so ready a means of preventing the calamities of wet and dry-rot. Surely the prevention of these evils should be inducement enough to lead to the extended adoption of Sir W. Burnett's patent, even were the woody fibre thus treated not rendered almost incombustible.

But when we add to the preservative effect of chloride of zinc on timber, as regards wet and dry-rot, the important statement that such Burnettised timber is, in common parlance, all but incombustible, it does seem most strange, most perverse, I may say, that its employment is not universal.

Much difference of opinion has existed concerning the most advantageous time for felling timber. Botanical and chemical considerations, however, afford a safe rule of guidance in this matter. Different woods require to be cut at different times, according as the hard part, termed by botanists, "*duramen*," or the soft part, termed "*alburnum*," is the portion of the wood to be chiefly employed. In all cases it is desirable that timber should contain the minimum amount of sap or natural juice of the tree; and as this sap merely circulates in the external soft part, or alburnum of trees, the deduction follows that soft woods, such as willow, elm, lime, poplar, &c., should be felled in mid-winter, before the sap has begun to rise, otherwise the presence of the vegetable juice would contribute to decay. Hard woods may be felled at any time; but, speaking generally, the most advantageous time for felling all varieties of wood, is mid-winter; the next most advantageous time is mid-summer, a period at which the chief portion of sap has found its way into the extreme branches of the tree. Spring may be considered as the worst of all periods of the year for this operation.

In this short discourse on woody fibre, I have not diverged into the collateral paths which a study of the matter suggests. I have not occupied your time with the manufactures of cotton, hemp, or flax. In a subject which admits of such discursiveness, which brings together arts and manufactures, diverse in every other respect, I have thought it well to concentrate my especial

attention on some prominent facts belonging to the subject. Now it appears to me that the most prominent fact in connection with woody fibre is involved in the discovery of a means of preventing the decay of timber and, at the same time, diminishing the list of those frightful conflagrations which, in spite of all the care of architects, and the repressive means of our fire-brigades, are so frequent and so terrible.

LECTURE VII.

ON THE CHEMISTRY OF FATTY BODIES: INVOLVING THE MANUFACTURE OF SOAP AND CANDLES.

THE subject of my lecture to-day involves two most important industrial processes, the manufacture of *candles* and of *soap*. In the former, chemistry has effected some extraordinary improvements; in the latter, chemistry, on account of fiscal restrictions, has not been placed under conditions favourable to a display of its advantages.

I need not say that both these operations involve the use of oils, fat, or their immediate derivatives. We shall, therefore, have to commence our investigations by studying the nature of fatty bodies, their chemical reactions, and the succession of improvements by which, instead of the natural crude fat or tallow, certain portions of it have been extracted and specially employed.

Oils admit of a general binary division into two grand classes, the *volatile* or *essential*, and the *fixed* oils. Two leading characteristics in the former class are expressed by the appellations "*volatile*" and "*essential*," inasmuch as they are far more readily vaporisable than

the members of the second class; and, moreover, they are odorous, and dissolve in alcohol, giving rise to fluids usually termed *essences.*

It is not, however, of essential, but of *fixed oils* that I have particularly to speak this morning. These bodies, although varying physically no less than chemically from each other, present only slight differences of ultimate constitution. All of them are made up of oxygen, hydrogen, and carbon, differing somewhat in their quantitative relations, as shown in the following table:—

	Carbon.	Hydrogen.	Oxygen.
Olive oil . . .	77·21	13·36	9·43
Almond oil . .	77·49	11·48	10·82
Linseed oil . .	76·01	11·35	12·62
Nut oil . . .	79·77	10·57	9·12
Castor oil . .	74·17	11·03	14·78
Whale oil . .	76·13	12·40	11·80
Spermaceti oil .	78·91	10·97	10·12
Hog's lard . .	79·09	11·16	9·75
Suet . . .	78·99	11·70	9·30
Butter . . .	65·60	17·60	16·80

But it is the *proximate,* not the ultimate, composition of fixed oils, which is of chief interest to the manufacturer; and in no department of chemistry has experimental assiduity been more rich in its results than here. We are indebted chiefly to M. Chevreul for much of the information we possess in relation to the interesting bodies termed fatty acids.

Although a fixed oil or fat may at first strike an observer with the idea of its possessing a homogeneous

composition, yet even without specific experiment, certain phenomena manifest themselves at variance with this supposition. Thus, for example, when olive oil is exposed for a certain time to a low temperature, it separates into two parts, one of which is solid and the other fluid. Again, if common tallow be compressed between folds of bibulous paper, a liquid oily material is absorbed by the paper. Facts of this kind are in themselves suggestive of the compound nature of fixed oils and fats; but it remained for M. Chevreul to demonstrate, by chemical means, the exact proximate constitution of these bodies; to separate the proximate components, designate them, and suggest the purposes to which they might be applied. M. Chevreul made the important discovery that every fixed oil or fat was compounded of two or more fatty bodies, each differing as to its condition of fluidity, and in some other respects. He discovered, moreover, that each of these separate oils or fats was really a *salt*, according to one acceptation of that term; namely, a combination of an *acid* with a *base*.

These *fatty acids* differ amongst themselves, and hence arise differences in the oils which they generate; but the base appears to be in almost all cases the same, and is termed *glycerine*. The number of fatty acids being very great, I shall chiefly direct my attention to the most commonly existing ones—namely, *oleic* or *elaic*, and *stearic* acids—the former constituting, when united with the base glycerine, the *soft* oily portion of tallow or lard; the latter, its *hard* or more solid portion.

Perhaps the appended table will afford an idea still more precise concerning the proximate composition of oils and fats:—

PROXIMATE COMPOSITION OF OILS AND FATS.

Fat and Oil	{ Stearine. Oleine.	
Stearine	{ Stearic Acid Glycerine	} Fats and Oils, or Stearoleates of Glycerine.
Oleine	{ Oleic Acid Glycerine	} Fats and Oils, or Stearoleates of Glycerine.

By referring to this table it will be seen that fats and oils are composed of two principles—oleine and stearine, or others in some degree kindred; and these may be regarded as salts, in which the glycerine acts the part of a base, and stearic and oleic acid respectively the parts of acids. Hence it follows that fixed oils and fats may in the aggregate be regarded as *stearoleates of glycerine.*

With regard to glycerine, stearine, and stearic acid, their ultimate components may be observed by reference to the accompanying table:—

Glycerine	C_6 H_8 O_6
Stearine	C_{142} H_{140} O_{16}
Stearic Acid	C_{136} H_{132} O_{10}

And the relations subsisting between stearic acid, glycerine, and stearine, will be rendered evident by the accompanying diagram:—

Glycerine	C_6 H_8 O_6
Stearic Acid	C_{136} H_{132} O_{10}
Stearine	C_{142} H_{140} O_{16}

Having thus indicated the general type or composition of oils and fats, I shall now sketch the operations of the soap and candle manufacture, limiting my remarks, for the sake of precision, to oleine and stearine, and oleic and stearic acids.

Oleine and stearine we have seen to be composed respectively of oleic and stearic acid, united to the base glycerine. It should follow, therefore, from a consideration of elementary chemical principles, that if these substances be really salts, either should be susceptible of yielding up its base "*glycerine*," in favour of some base possessing a stronger affinity for the oily acid. This kind of decomposition, in point of fact, readily takes place under proper conditions, and the resulting salt is a *soap*, varying in its nature according to the *base* employed. Soaps, ordinarily called such, that is to say, soaps employed for detergent purposes, are compounds of oleic and stearic acid, with potash or soda. Instead of the latter base, lime may be employed, and, indeed, is largely employed, as we shall find hereafter, at a preliminary stage of treatment in the candle manufacture. Lime soap, however, being very insoluble in water, has no detergent properties: on the contrary, it diminishes the ordinary detergent power of water. This fact is sometimes unpleasantly illustrated when we do not wish it. The curdiness produced in hard water when employed with soap for cleansing purposes, is due to the formation of lime-soap, or a soap of kindred nature: for all the alkaline earths, and the greater

number of metallic oxides, are capable of uniting with oily acids, and generating soaps. Although potash and soda both yield, by combination with oily acids, good detergent soaps, they differ in one leading physical quality. Potash yields *soft*, and soda *hard* soaps. If the composition of economic detergent soap be so simple as I have represented it to be, it may be asked, whence and for what purpose arise all the different varieties of soaps which are sold? Omitting from consideration altogether the ornamental scented fancy soaps, in which the use of the extraneous agents is manifest, and passing on to the consideration of sand-soap, pumice-stone soap, and materials of that kind, it may be stated generally, with respect to them, that the superadded material is altogether for the advantage of the seller, and disadvantage of the purchaser. The soap is rendered heavier by such incorporation, and less efficient.

Frequently, however, soaps are vended under the characteristic name of some material, not one particle of which do they contain. This remark applies to the greater number of varieties of the so-called honey soap, the chief portion of which is totally void of honey; and in no case is a larger amount of honey incorporated than may suffice to satisfy the conscience of an honest manufacturer.

The common yellow soap derives its peculiar colour and odour from a mixture of rosin with the oleaginous and alkaline materials; but other ingredients not un-

frequently find their way into this soap, thus accounting for the varieties of shade and other qualities which this kind of soap presents. The ornamental soap manufacture is one of great delicacy. It is a branch of the soap-making process in which we are, or rather have been, greatly fettered, on account of our excise regulations—not only by their direct bearing on soap, but in consequence of their relations to alcohol, an agent which is very extensively used in the fabrication of toilette soaps, not only by assisting to form the essences with which they are scented, but by contributing directly to the existence of certain peculiar soaps. The class termed *transparent soap* all owe their peculiarity to alcohol, in which their ingredients are dissolved, instead of water, as ordinarily employed in other soaps.

The chemical property possessed by soap, of readily dissolving in alcohol, renders the solution a valuable qualitative test for discriminating approximatively the presence or absence of metallic bases in water. If an alcoholic solution of soap be poured into distilled water, no perceptible change ensues; but if the same solution be poured into any ordinary variety of natural terrestrial water, a certain amount of turbidity results, according to the amount present of earthy or metallic bases; hence, by this test, the comparative softness or hardness of different waters may be rendered evident.

Passing on now to the manufacture of *candles*, we shall find it to be allied to the manufacture of soap, not only by the circumstance of fatty matters being em-

ployed, but by the preliminary employment of a soap-making operation. This remark at least applies to the varieties of candle termed palm oil, and composite; varieties which have almost driven the old tallow candle out of the field, and vie with, if indeed they do not transcend, those of wax and spermaceti. The old process of tallow-candle manufacture scarcely requires notice, except for the purpose of comparing it with the beautiful improvements consequent on the discovery of the compound nature of oils and fats by M. Chevreul. Tallow candles, as we all know, are of two kinds. In one, the tallow is caused to adhere to the wick by dipping the latter in it; hence candles thus prepared are called "*dips.*" In the other kind the wick is imbedded in tallow by casting the latter round it in a mould; hence the derivation of the term "*mould candles.*"

By whatever means the tallow may be made to envelop the wick, the objections to tallow, as a candle-making agent, remain. The substance being composed of two fatty bodies—one oily, and the other hard—the resulting candle is devoid of homogeneity. The soft part melts first, thus causing the formation of channels around the burning candle—a result termed "*guttering.*" Nor is this the only objection to tallow candles: the material of which they are composed is not mere tallow, but it contains shreds and fibres of decomposing animal tissue, which evolve a disagreeable smell. Add to these disadvantages the necessity for snuffing, which tallow candles require, and enough will have been stated

to show the desirableness of finding a substitute. In the infancy of chemical science, the manufacturer's only hope of turning out a superior candle consisted in discarding tallow altogether, and employing in its place some material, naturally existing, which possessed the desired qualities of sufficient hardness and combustibility. Of these materials, wax was the first to be employed; then followed the use of spermaceti; both of which are good materials for the purpose, and are still used, although they are displaced more and more, every year, by the the development of the chemical art of candle manufacture from certain non-detergent soaps as a basis. As the principles upon which the stearic acid candle manufacture depend were first developed by a French philosopher, so the first successful application of these principles to practice was made in France; and here, perhaps, it will be desirable to present a general sketch of the progress of this manufacture, from the first scientific investigations, relative to the composition of fatty bodies, to the present time.

The earliest labours of Chevreul on this subject date as far back as 1811, previous to which time the compound nature of oils and fats was not suspected. His first great discovery, announced to the Academy of Sciences in his paper dated July 5, 1813, was that of the compound nature of oils and fats already adverted to. It showed that fat was not, as previously supposed, an unmixed organic substance, but a *salt*. Glycerine being the true base, combined with a fatty acid, the margaric—from

margarita, a pearl, on account of the pearly hue of its crystals. Stearic and margaric acid may, for all practical purposes, be regarded as synonymous. Subsequently, on the 2nd of November, in the same year, Chevreul read to the Academy a second paper, on the discovery of a second fatty acid, a liquid one. This he called the *elaic* or *oleic* acid. In the years 1814, 1815, 1816, and 1818, Chevreul published other valuable papers relative to the fatty acids; and, still continuing his labours, Berthollet and Gay Lussac advised him to collate all his published discoveries on this subject, and publish them in a separate work. Having applied himself to the task of this collection during two years, at length, in 1823, the work appeared, under the title of "Chemical Researches on Fatty Bodies of Animal Origin." A more talented exposition of the laws of any one special chemical subject does not exist; even at this day it remains the great text book for reference in all that relates to the constitution of animal fatty bodies.

In the year 1825, M. Chevreul, in association with M. Gay Lussac, commenced a practical application of his discoveries to the candle manufacture. He was not, however, successful, and it ultimately remained for M. Milly, a French manufacturer, to successfully apply those principles which M. Chevreul had evolved. The manufacture of M. Milly was commenced in 1832, at Paris, near the barrier *de l'étoile*. Hence the origin of the name "*bougies de l'etoile*," subsequently applied to

the resulting candles. . Thus the stearic or margaric acid candle manufacture was at length established, and would doubtless have gone on improving, without the collateral stimulus of a premium. The progress of the manufacture, however, was considerably hastened by a prize of 4,000 francs, offered, in 1832, by the Society of Encouragement, of Paris, to the manufacturer who should have brought into the market at least 2,000 kilogrammes, about two tons, of the candles, at the price of two francs the kilogramme (about 8d. per pound), the candle to fulfil the following conditions :—

To give out at least as much light, and to last as long, as ordinary wax candles.

Not to give off disagreeable smell or smoke.

Not to run more than wax or sperm candles.

To be hard and dry to the touch; the kind of material subject to no restriction, save that of having a melting point not below 50° c. (122° Fahrenheit).

No claimant having presented himself for this prize during the years 1833 and 1834, the adjudication was postponed to 1835. In May, 1833, M. Payen made a report on the *bougies de l'étoile*, the sale of which was then represented as amounting to 25,000 kilogrammes (about 25 tons) annually, the price being 2 francs 5 centimes wholesale, and 2 francs 25 centimes retail, per half kilogramme—about 1s. 6d. and 1s. 8d. per pound. These candles were stated to be fully equal to wax—indeed, superior to them in certain respects; and thus two conditions out of the three, proposed by the Society of

Encouragement, were supplied by the manufacture of MM. Motard and Milly: the quality and the quantity stipulated, but not the price. On this occasion the Society voted a silver medal to MM. Motard and Milly, and inserted a vote in their minutes to the effect that they believed, judging from the rate of progress in this manufacture, the money-prize would be speedily carried off.

The process employed by M. Milly in his candle manufacture was almost identical with that suggested by Chevreul for separating the fatty acids uncombined with glycerine. It is a process still extensively employed, here as well as in France, notwithstanding that in our largest candle manufactory, that of Price and Co., another process is adopted, although it accomplishes a similar final result.

I shall now present a general indication of the different stages of candle manufacture where the lime-soap process is employed, which constitute a direct application of the process of M. Chevreul; and, whilst on this subject, I must express my obligations to Mr. Hale, of Queen-street, Cheapside, and Orange-street, Borough, for the facilities this gentleman has afforded me in visiting his manufactory, and learning, by inspection, the processes there carried on.

The scheme of operations by which the hard fatty acid is obtained and adapted to the manufacture of candles, assumes in the factory of Mr. Hale the following order:—

1. Saponification by pure lime.
2. Pulverisation of the oleostearate of lime.
3. Decomposition by sulphuric acid.
4. Washing the oleostearic acid.
5. Crystallisation of fatty acids.
6. Breaking up.
7. Pressure cold.
8. Pressure hot.
9. Washing the concrete acids.
10. Casting, colouring, &c.
11. Polishing, cleaning, &c. *

Quick lime being added, at a certain temperature, to the tallow or other fatty body employed, the usual play of affinities occurring during the process of saponification takes place. Stearine and oleine are resolved into stearic and oleic acids, glycerine being set free. The concrete oleostearate of lime, which is a true lime-soap, technically called "*rock*," being now pulverised, is decomposed by the addition of sulphuric acid, when sulphate of lime results, and oleostearic acids are set free, crystallised, broken up, and exposed, *cold*, to the operation of hydrostatic pressure, by which

* Jules Cambacérès proposes to use alumina instead of lime, in order that valuable sulphate of alumina may result as a secondary product, instead of valueless sulphate of lime. But alumina (clay) does not directly combine with the fatty acids. It readily combines, however, with the acid part of alkaline soaps, setting free the alkali. The process of beginning with an alkaline instead of an earthy soap is suggested as the basis of rendering the operation cheaper.—*L'Institut*, No. 994, January 19, 1853, p. 20.

treatment a certain quantity of oleic acid is expelled. It is next exposed *hot* to a repetition of this pressure, by which a still farther separation of oleic acid takes place. Stearic acid, tolerably free from oleic acid, now remains, and, after being washed, is moulded into candles. Occasionally a little gamboge is melted with the stearic acid, previously to the final operation, for the purpose of imitating the colour of wax. The prejudice which renders this colouration necessary, is confined to England exclusively. The continental nations and the colonies prefer candles which are absolutely white, and this preference is an indication of their good taste.

It remains now to mention the scheme of operations followed in Price's manufactory, by which sulphuric acid is made to take the place of lime. The process is as follows :—Six tons of raw material (palm oil) are exposed to the combined action of $6\frac{3}{7}$ cwts of concentrated sulphuric acid, and a temperature of 350° Fahrenheit. By this process the glycerine is decomposed, large volumes of sulphurous acid are given off, and the originally complex fat is changed into a combination of fatty acids, the colour of which is very dark, and the melting point very high. This being washed, to free it from charred matter and adhering sulphuric acid, is transferred to a still, from which air is excluded. The original idea was to effect the exclusion of air by means of the air-pump; it is now far more easily accomplished, however, by the admission of steam, the latter being previously heated by a system of pipes resembling the hot-blast apparatus

used in the manufacture of iron. The concrete fatty acids now distill over, and being subjected to the ordinary manipulative processes, are made into candles in the usual way.

This process of candle manufacture is a consolidation of the principles involved in several patents, the first of which was taken out March, 1840, by Mr. George Gwynne; the second in 1842, taken out in the name of Mr. W. C. Jones; the third in the names of Jones and Price, in 1842. Other patents have succeeded these; but details rather than principles being involved in them, they do not require to be specially adverted to.

In the early days of the stearine candle manufacture, understanding this term in the fullest sense, as comprehending all hard fatty acids, considerable embarrassment was occasioned by the tendency of these acids to crystallise. To diminish this crystallising force, substances were incorporated with the fatty acids. The chief substance employed was arsenious acid. It effectually prevented crystallisation, but was productive of danger to health. Had no other cause been in existence, popular animadversion would have soon driven these arsenic candles completely out of consumption, although to find a substitute for the arsenic was long a desideratum. At present, crystallisation is prevented by the very simple provision of turning the fatty acids into the mould just at the instant of their setting, taking care that the moulds be not of a higher tem-

perature than the semi-fluid acid. Wax is equally efficacious with arsenic in preventing the crystallisation of stearine, but the expense of wax is an objection; and, indeed, by properly regulating the temperature at which the casting is effected, admixture of all foreign material is rendered unnecessary.

The perfection of a candle very much depends upon the nature of its wick. Accordingly, great attention has been paid, and many ingenious devices have been had recourse to, for securing the conditions desired. A candle-wick may be regarded as a congeries of capillary tubes, the function of which is to supply the candle flame with the due samount of liquefied fatty matter necessary to combustion. This is the primary function of a candle-wick; but in order to render it efficient, numerous collateral properties must be superadded. So long as the wick remains enveloped by the flame, it cannot undergo complete combustion for want of contact with atmospheric oxygen. If, therefore, some provision be not made for effecting this contact, the wick will require snuffing, and will hence be imperfect. Various means are had recourse to for accomplishing this contact, the chief of which are the following: either the wick is twisted double, in such a manner that the act of uncoiling, consequent on combustion, brings the two ends into atmospheric contact; or the same effective result is accomplished by the simpler method of weaving a single wick in such a manner that the lateral tension of its filaments is unequal, from the

existence of which conditions it results that the wick, on being freed from restraint by the liquefaction of the fatty matter surrounding it, bends on one side, and thus presents its extremity to the atmosphere. Nor is the provision just mentioned sufficient to constitute a good wick, the relative perfection among which (other circumstances being equal) will be determined by the amount and the nature of the ash formed at the burning extremity. If the ash be of such a kind as does not readily agglomerate, but disperses itself irregularly in loose flocculi, guttering of the candle will result, on account of the occasional deposition of these flocculi on the external rim of unmelted fatty matter. This long continued to be an unremedied defect in the earlier days of stearic acid candle manufacture. It is now obviated by steeping the wicks in a weak solution of borax, which substance, by fusing round the particles of ashes, consolidates them into a kind of glass, and regulates the velocity of combustion so accurately, that the fused ashy particles are no longer deposited irregularly on various parts of the candle, but are dropped into the central well of melted fatty matter.

It may not in this place be unadvisable to offer some notice of *paraffine* as a substitute for fats or fatty acids in the manufacture of candles. Formerly paraffine was only procured in small quantities from wood-tar; it is now obtained much more plentifully, and admirable candles have been made of it.

Pure paraffine is a white substance, destitute of

smell and taste, and has a soft satiny feel between the fingers. Its sp. gr. is 0·87. It melts at 112° Fahr., and boils at a higher temperature, with the exhalation of white fumes. It burns with a clear white flame. Its composition is isomeric with that of olefiant gas, the chief illuminating ingredient of oil and coal gas—being, in fact, a solid bicarburet of hydrogen, or, as it has been popularly termed, "solid gas."

It will be quite unnecessary here to give any account of the discovery of this product by Reichenbach, or of the mode of obtaining it from beechwood tar, its original source. The quantity of this tar obtainable is too small to allow of the separation of its paraffine to advantage; we therefore look to the 2,830,000 of acres of Irish bog-land, and to the exhaustless beds of British coal, for our supplies of this product for commercial purposes.

The commercial processes at present before the public, are those of Mr. Reece from peat, and Mr. Young from coal.

Mr. Reece's method of obtaining paraffine from peat is as follows:—

The peat, or turf, is submitted to combustion in a vertical furnace, the part of it above the fire or grate-bars being lined with, or made of, iron; the ash-pit below the bars is closed, a pipe leading into it for supplying a blast of air to the furnace; the top of the furnace, which is the only aperture into it for the purpose of charging, is closed by a plate, which is

removed when a charge is made, the object being to prevent the products of combustion from escaping into the atmosphere; at the upper part of the furnace a pipe for conveying off the gaseous products is connected, the other end passing into a closed receiver or cistern, containing water, the end of the pipe dipping below the surface of the water, to prevent any return of the gaseous products; to the upper part of this cistern, and above the surface of the water, is another pipe for conveying away the gaseous products; this pipe is the first of a series of horizontal pipes placed in a vessel of water; they act as a condenser, within which the vaporous products from the combustion of the peat in the furnace are condensed; the gaseous products remaining uncondensed in the condenser are conveyed away by a pipe, and applied to any purpose required; the tarry and other condensed matters are lastly drawn off into any convenient recipient.

To obtain the paraffine from the tarry product of the distillation of peat, conducted either in the way above described, or in the ordinary process of carbonisation, in closed vessels, or otherwise, Mr. Reece proceeds as follows:—The tarry product is subjected to the process of distillation until about one half of it is distilled over, at as low a temperature as possible; the other portion is then distilled over into a separate receiver, or vessel; this second portion of the distilled products consists of the paraffine and the liquid paraffine, and a small portion of liquid hydrocarbons.

The product is of a dark yellow colour, and the paraffine exists in a state of crystallisation; this is separated from the liquid by filtration through fine hair sieves, or other means; the solid paraffine is then melted, and cast into moulds about two inches deep; it is submitted to pressure, and again distilled and re-cast, and again submitted to pressure in a stearine hot-press, to extract further the liquid matters, taking care that the temperature is raised as little above 100° Fahr. as possible. The substance may then be made into candles. The liquid paraffine is distilled to remove the colour, and, if necessary, that operation may be repeated, and the liquid paraffine employed for burning in lamps.

Mr. Young's process of obtaining paraffine from coal is as follows:—The coals are to be broken in small pieces of about the size of a hen's egg, or less, for the purpose of facilitating the operation; the coal is then to be put into a common gas-retort, to which is attached a worm-pipe, passing through a refrigerator, and kept at a temperature of about 55° degrees Fahr. by a stream of cold water. The temperature of the refrigerator should not be too low, lest the product of the distillation should congeal and stop up the pipe. It is found that a temperature of about 55° Fahr. is sufficient. The retort, being closed in the usual manner, is then to be gradually heated up to a low red heat, at which it is to be kept until volatile products cease to come off. Care must be taken to keep the

temperature of the retort from rising above that of a low red heat, so as to prevent as much as possible the desired products of the process being converted into permanent gas. The coke, or residue, may then be withdrawn from the retort, which, being allowed to cool down below a visible red heat (to prevent waste of the fresh material to be introduced), may be again charged with a quantity of coals, to be treated in the manner above described. The crude paraffine oil distilled, or driven off from the coals as a vapour, will be condensed into a liquid in passing through the cold worm-pipe, from which it will fall into a vessel, which must be provided to receive it.

Instead of obtaining the whole of the paraffine oil by distillation, or driving off, as just described, a portion of it may in some cases, if thought desirable, be run from the retort through an opening and a pipe to be provided in the anterior and lower part of the retort for that purpose, after it has separated from the coal, and assumed a liquid form.

It is, however, preferable in every case to distil or drive off the whole of the paraffine oil to be obtained from the coal. The production of the desired results from a charge of coals in a retort will be known to be finished by the liquid ceasing to run from the worm. The crude product of this process is an oil containing paraffine, which is called paraffine oil. This oil will sometimes, upon cooling to a temperature of about 40° Fahr., deposit paraffine.

Other arrangements of apparatus may be used for subjecting coals to the process for obtaining paraffine oil therefrom, as already described; but the apparatus above-mentioned is preferable, as being well known and easily managed. But in order to obtain the largest quantity of crude paraffine oil from coals by means of this process, and produce the smallest quantity of permanent gas by the action of the heat employed, whatever may be the apparatus used, care must be taken to heat the coals gradually, and to apply the lowest temperature necessary to complete the operation. During the distillation or driving off above described, a permanent gas will be produced, and this gas may either be collected or suffered to escape, as may be thought expedient. The crude oil thus obtained is purified in the following manner:—the oil is poured into a cistern, and heated (by steam-pipe or other means) to a temperature of about 150° Fahr. When thus heated, water and undissolved impurities contained in the oil will separate more readily from it than when cold, and, the oil being left in a state of rest, and kept warm for about a day, many of those impurities will fall to the bottom of the cistern, and the oil may then be run off into another vessel, leaving the residuum behind. The oil is then distilled, for which operation an iron still is used, with a worm pipe connected to it, passing through a refrigeratory apparatus, kept at 50° Fahr.; the still is now heated by a fire underneath, which must be kept up until the whole of the oil has

been distilled over, and it will then be found that the still contains some dry carbonaceous residuum, which should be taken out before the still is again used. The oil is to be run from the condensing apparatus as it distils over, into a leaden vessel, where, to each 100 gallons, are gradually added ten gallons of the oil of vitriol of commerce. After this mixture has been well stirred for about an hour, it is allowed to remain at rest for about twelve hours, so that the oil of vitriol and the impurities with which it has combined may settle at the bottom. The supernatant oil is then drawn off into an iron vessel, and to each 100 gallons are added four gallons of a solution of caustic soda, of a specific gravity 1·300, water being 1·000. The soda and oil are stirred together for about an hour, so as to neutralise any acid which may remain in the oil, and also take up any impurities capable of combining with it, after which the contents of the vessel are allowed to remain at rest for about six or eight hours, so that the solution of soda may subside, and then the supernatant oil is to be drawn off, and again distilled in the same manner as already described. Paraffine oil obtained from the last-mentioned distillation contains a fluid more volatile than paraffine, and a considerable portion of this fluid may be separated from the oil, and obtained in a separate state, as follows:— The oil is put into an iron still, connected with a worm pipe passing through a refrigeratory apparatus; half of its bulk of water is now added to the oil, and

the whole boiled for about twelve hours, water from time to time being added, so as to keep about the same proportions of oil and water in the still.

The volatile fluid will pass over along with the steam, and be condensed in the worm pipe by the refrigeratory apparatus. This fluid will be clear and transparent, and, as it is lighter than water, it separates on standing from the water with which it will be mixed as it leaves the still. This fluid may be burnt for the purpose of illumination, or applied to any other useful purpose for which it may be suitable. The last-named process will separate the greater portion of the volatile fluid before-mentioned from the oil, but a larger quantity may be separated by prolonging the operation. The oil left in the still after the completion of the process lastly described is then to be carefully separated from the remaining water (upon which it will float), and conveyed into a leaden vessel, where to each 100 gallons are added 2 gallons of oil of vitriol. This mixture is to be well stirred for six or eight hours, after which it is allowed to stand undisturbed for 24 hours, in order that the vitriol may settle to the bottom of the leaden vessel, carrying with it all impurities with which it has combined. The supernatant oil is now to be drawn off into another vessel, and to each 100 gallons there are added 28 pounds of chalk, ground up with a little water into a thin paste. The oil and chalk are then to be well agitated until the oil becomes entirely freed from any trace of sulphurous acid, which may

easily be known by heating a little of it in a glass retort, and testing its vapours by moistened blue litmus-paper. If the vapours change the colour of the litmus-paper to red, the oil must be treated with more chalk. This oil is to be kept warm, say at 100° Fahr., in any convenient vessel for about a week, to allow impurities to settle and it is then fit to be used for lubricating purposes, either by itself or mixed with an animal or vegetable, oil, or it may be burnt by itself in argand lamps for the purposes of illumination.

To extract paraffine from the purified paraffine oil, obtained in the manner described, the oil is to be cooled to a low temperature, say to 30° or 40° Fahr., and the lower the temperature the larger will be the quantity of paraffine separated from the oil. In this way paraffine is made to crystallise, and in this state it may be separated from the oil, by filtration through woollen or other cloths, and then squeezing it in a powerful press, by which means it will be made sufficiently pure to be employed for lubricating and some other useful purposes. But the paraffine may be further purified, if required, by treating it several times, at a temperature of about 163° Fahr., alternately with its own bulk of oil of vitriol, and with a similar quantity of solution of caustic soda (of the specific gravity already mentioned), until the paraffine ceases to render the oil of vitriol black. It is then to be washed in a weak solution of soda, and lastly with boiling water, until the water ceases to change the colour of red litmus-paper.

To obtain paraffine from paraffine oil, the oil must be put into a still, and one-half or more of its contents distilled over. The portion then remaining will contain a much larger proportion of paraffine than the paraffine oil at first put into the still contained. This residue being then distilled over into a separate vessel, and allowed to cool, paraffine may be separated by filtration and squeezing in cloths, and also purified by treatment with oil of vitriol and soda, as before described. Paraffine oil, from which paraffine has been separated as before described, still contains paraffine in solution, and is suitable for lubricating or lighting purposes, as already mentioned. The coals best adapted for this purpose are such as are usually called parrot coal, cannel coal, and gas coal, and which are much used in the manufacture of gas for the purpose of illumination, because they yield, upon distillation at a high temperature, olefiant and other highly illuminating gases in considerable quantities; the earthy matters contained in these coals do not interfere with the performance of the process.

Paraffine cannot be employed alone for the manufacture of candles, but it requires to be diluted, if one may so term it, by admixture with wax, spermaceti, the fatty acids, and other substances usually had recourse to in this operation.

APPENDIX TO LECTURE VII.

COLLATERAL INFLUENCES OF THE DISCOVERIES OF M. CHEVREUL.

BEAUTIFUL as are the chemical principles which it was the good fortune of M. Chevreul to make known as the result of his masterly investigations concerning the nature of fatty bodies—useful as are their applications to the immediate purposes of candle manufacture—they have a political and a social significance, grand in its present aspect, portentous in its futurity. The greatest opprobrium of humanity, the foulest stain upon the escutcheon of civilisation, the crime before which the enormities of a Caligula pale, and the horrors of the Inquisition at its worst epoch, were, by comparison, as amenities—the African slave-trade seems destined to fall before the influence of a candle; the sale of negroes at the delta of the Niger is already checked by the consequence of the discovery of some fatty acids in a Parisian laboratory! The beneficent result for which philanthropy pleaded in vain, and well-meaning enthusiasts proposed impracticable schemes, and travellers perished, and wars, and fevers more terrible than wars,

were fruitlessly encountered, seems likely to be accomplished by the result of a chemical discovery!

It is a circumstance to be lamented, but it is nevertheless a truth, that mankind, viewed in the aggregate, are but little amenable to moral obligations. Any mere difference of educational acquirements or religion, seems to have little or no influence here. Civilised or savage, Christian, Mussulman, or Pagan—expediency, not the moral perception of right and wrong, is the active principle of governments and communities. If Europe affords an illustration of the truth of this, what right have we to expect a higher code of morality in Africa? Nevertheless, on the assumption of the existence of such a code, and the means of giving it effect, philanthropic efforts directed towards the abolition of the African slave-trade have been based.

If interest *expediency* be the strongest actuating cause of nations and communities, all rational efforts to diminish the slave-trade by primary influence, or, in other words, influence exercised at its source, will be based on appeals to an influence which now actuates the African to enslave and sell his fellow-men—the influence of lucre, of commercial profit, of gain. Once establish demand for an article more valuable than slaves—a product requiring application of agricultural labour for its extensive development—once render the skilled labour of the negro more remunerative than the sale of his body,—then the slave-trade will cease.

The commercial capabilities of Africa, the import-

ance of the products it now yields, the facilities for increasing them and extending their number, the mental characteristics and the degree of civilisation to which the African races have attained, are topics to which much less consideration has been given than their importance demands. Because the border tribes of Western Africa sell slaves, the unjust inference has been adduced that the whole negro population is addicted to this traffic. Because amongst these border tribes the slave-trade takes the leading position, it has been falsely assumed to result from an innate proclivity to this form of traffic. An impartial consideration of the circumstances will not bear out the assumption. To account for the sale of slaves, it is unnecessary to invoke the existence of any specific amount or specific kind of tendency in the African disposition. The negro chief makes war, takes prisoners, and sells them, simply because the profits are enormous. Such persons as may doubt the sufficiency of this explanation, can test the validity of the doubt with tolerable accuracy thus:—Suppose the conditions are reversed; suppose a premium sufficiently high to be set upon white men by African chiefs—then, will it be supposed that, except for legal impediments, those men whose moral perceptions do not interfere with their buying negro slaves, and subjecting them to all the horrors of the middle-passage, would hesitate to establish a slave-trade in the opposite direction?

There appears to be no limit to the amount of com-

merce which might be transacted with Africa if we could only succeed in rendering the vast tracts of its interior accessible. Geographical and sanitary impediments have hitherto presented insuperable obstacles to the accomplishment of this object on a large scale; but if the concurrent testimony of those who have resided long in the country, and know it well, is worth anything, the accomplishment, far from being impossible, is not even difficult. Only one attempt has been hitherto made in this direction. It was made by the unfortunate expedition of 1842, and proved an utter failure. Happily the causes of this failure are not hidden: they are evident. Many of them were foreseen; and it is not too much to say that many were directly the consequences of measures taken with a view to their prevention. The whole of our accumulated experience, relative to the sanitary influence of Western Africa, proves that all who remain in that region, even for a short time, must succumb to the local or endemic fever of the place. In spite of all the aids which medicine has suggested, or can suggest, the mortality consequent on this fever is very high, even when the subjects of its attack are comfortably housed in fixed habitations, free from collateral anxiety, and provided with the best of care. But the attack once over, the individual is, as the rule, exempted from all further domination of the malady; he is acclimated to the influence, and may thenceforward spend his days in the unhealthy regions of Africa in the enjoyment of very

tolerable health. Any expedition which shall penetrate unharmed towards central Africa, through the unhealthy littoral belt, to which the miasmatic influences are restricted, must either consist of acclimated whites, or of natives, the latter not being subject to the attacks of coast fever.

The unfortunate expedition of 1842 was not of this kind. Its members were made up of a few natives, of crews taken from ships on the sea-coast of Western Africa, and of persons who were strangers even to such proximity with the source of febrile influence as sailing near the coast of Africa involves.

The doctrine of acclimatisation was totally repudiated—the accumulated medical experience bearing upon this point was ignored. Theories of infection, unproved, if not visionary, were adopted as proven facts. Constitutions were to be rendered fever-proof by the daily ingestion of quinine. The germs of infection were to be scorched and destroyed by corrosive fumigants, and blown out of the favoured vessels by the motion of ventilating fans. This memorable expedition is too well known to require mention—too melancholy in its results for the mind needlessly to dwell upon. No expedition to central Africa on the large scale has been since attempted; but it will be forced on the consideration of the nations of Western Europe before the lapse of considerable time, by commercial necessities; more especially those having reference to the increased consumption of fatty bodies.

The discoveries of M. Chevreul proved that a raw fixed oil, or fat, being supplied, it might, by chemical treatment, be adapted to the fulfilment of numerous conditions; they showed, moreover, that it signified little whether the fatty body were of animal or vegetable origin. Its proximate constituents might indeed exist in various proportions of admixture; but, when separated, they would constitute series identical, or almost identical in kind. Before this grand discovery, the range of purposes to which fatty bodies could be applied was limited by their natural physical state. A thin oil, or soft fat, could not be applied for the manufacture of candles, nor could a thick, tallow-like substance be applied to the purposes of a lubricating agent. At present all this is changed. Give but a fixed fatty body, and the chemist, by separating its parts, can render it adapted to all the numerous purposes for which oils and fats of any kind are used. A contemplation of this discovery in all its bearings, will tend to show a harmony existing between the development of science, and the political and social development of the world. The vast applications of machinery which have followed, and have been dependent upon, the discovery of the steam engine, demanded an enormous supply of lubricating fluid. The demand was long supplied from animal fats; but these being insufficient in quantity, the vegetable, and even the mineral world, were had recourse to; but, even at this time, the demand is greater than the supply. Now, the development of machinery is

still going on, whilst the supply of animal fatty bodies is stationary, or decreasing. Under these circumstances, it is no longer a choice that we open out the resources of the vegetable world—it is a necessity. Where, then, shall we go? The botanist tells us, to central Africa, where oily matters, of vegetable origin, are yielded in quantities to which no visible limits can be assigned. I have stated, that the supply of oil and fat from animal sources is stationary, or rather decreasing. Commercial statistics prove this; social, political, and scientific circumstances explain it. The vast quantities of tallow which have been long thrown into commerce from Russia, South America, and Australia, are the consequences, or at least the concomitants, of a barbarous social condition. The tallow from these sources, and the skins, have been the only products of value obtained from the slaughtered animal. The flesh has been mere offal, and thrown to waste. The progressive destiny of the world is inconsistent with the perpetuation of a scheme like this; that destiny which shines forth under so many aspects—now in the form of science, now in the form of political change, now in the desolation of a war, by which inferior races are swept away, and beings of higher intellectual powers become dominant; now in the form of treasures brought to light in distant quarters of the globe—by the incitement of which nations, even the most attached to the place of their birth, rush forth in an exodus—that destiny is incompatible with the loose and slovenly economy of animal life, involved

in the breeding of animals for their mere hides and tallow.

As barbarous tracts become civilised, and population increases, those wide expanses of pasture-land which now sustain the tallow-yielding herds will gradually come under tillage. The number of animals bred will be regulated by the ordinary consideration influencing civilised people, the condition of food. Meantime the steam-engine and its myriads of oil-devouring satellites, will go on increasing. Oil *must* be obtained: if not from the animal world, it must be supplied from the vegetable. Africa is the only tract which can supply the demand; but thence the supply is illimitable. At present our general trade with Western Africa is chiefly, almost exclusively, confined to restricted portions of the coast belt. The chief seat of this trade is the delta of the Niger, which unfortunately is also the head-quarters of the slave traffic, which, during its feverish and irregular periods of activity, interferes with every branch of legitimate commerce. Notwithstanding the disadvantages under which our West African trade is at present carried on—notwithstanding that the slave traffic coexists with it at the same head-quarters, and that the resources of Central Africa have not yet been fairly opened, the legitimate traffic is considerable. It now represents the value of about one million sterling annually. No less than 20,000 tons of shipping from Liverpool are employed in the palm-oil trade alone.

Valuable though palm-oil be as a substitute for

tallow, this is by no means the principal source of African vegetable supply to which the attention of botanists is directed. The chea, or butter-tree, yields a fatty substance of greater natural purity, and is extended over a far wider region—that region being Central Africa. It is a curious fact, that the cocoa-nut palm never grows very far from the sea. The palm-oil palms also manifest a similar predilection, although not so well pronounced, for a littoral belt. They do not grow in Central Africa. Now, the latter region is the main source of slave supply; it is free from the influence of febrile malaria; and there, the chea-tree furnishes an illimitable supply of oily material—so pure, that the natives, although possessing cows in abundance, prefer using the vegetable butter. Even now, this material may sometimes be purchased at Liverpool at the same rate as palm oil, notwithstanding its passage through no well opened channel, from the centre of Africa to the coast. This fact is sufficiently expressive of the native profusion of the material.

The concomitant testimony of all travellers who have penetrated into central Africa, agrees in stating the amount of civilisation arrived at by the natives, to be far greater than for which credit is usually given them. They are prone to adopt, however inappropriately, the garments, the vessels even, and instruments of civilised life; thus demonstrating the existence amongst them of an enterprising commercial spirit, and that absence of prejudice, without which

such propensity could not take effect. Clapperton, speaking of the country of the Felatchs, states as an instance of the desire of the natives to obtain certain appendages to European civilisation, that at Sackatoo the capital, provisions were regularly sent him from the Sultan's table, on pewter dishes with the London stamp, and one day, he even had a piece of meat served up in a white wash-hand basin of English manufacture. Major Denham affords similar testimony. He tells us that the Bornou Arabs, or Moorish merchants, the only ones who hitherto have ventured into the country of the Felatchs, are treated with great liberality, and return after a few years' residence, in possession of large fortunes. The commodities in which they barter are chiefly of European produce—purchased at Tripoli, and carried to the remote regions of central Africa, under circumstances of danger and difficulty. When it is considered that their merchandise was purchased at Tripoli, at prices varying from 200 to 250 per cent. above prime cost, the final sums paid for them by the Felatchs may be inferred to be enormous, and some idea of the desire with which these people endeavour to obtain such European articles, may be arrived at.

Having established the existence in central Africa, of an inexhaustible field of production for vegetable fatty bodies—having established the fact that the people of those central regions are commercial in their tastes, free in their intercourse with foreigners, and liberal in their dealings—having finally established the fact, (without

which the preceding ones would have been unavailing) that the fatal fever of west Africa is limited to a comparatively narrow fringe of coast, certainly not extending beyond the limits of the Delta of the Niger—the practical means of approaching central Africa through a certain channel, available for large consignments, remains to be discussed. We must form a settlement above the Delta, at the confluence of the latter river and the Tchadda. Only one difficulty stands in the way of this—the fear of coast fever. Nor is the fear unfounded, so far as unacclimated persons are concerned. Such can hardly calculate on passing the malarious belt without succumbing for a time, at least, to the influence—a result totally incompatible with the regularity so necessary in commercial operations. The active communication between the coast and central trading position, should be carried on by crews of natives or of acclimated Europeans.

If a settlement were thus established at the point of confluence of the Niger and the Tchadda, the deepest recesses of Africa might be penetrated, the Niger alone furnishing a water-line of 2,000 miles in length, and the Tchadda, of 600. "By means of the Tchadda," says Dr. Kehoe, "the territory of Bornou could be reached, and, by the same channel, the extreme sources of the Bakrelabia, the White Nile, the Shary, and the Congo, could be gained by navigation—through the whole of the central, the most populous, civilised, and fertile portion of Africa, teeming with all the produc-

tions of the tropics, and inhabited by people already sufficiently civilised to be anxious for commercial intercourse with us, and to be further civilised by it.

"As none but the lowest tribes of Africans are ever made slaves, or leave their country, we are apt to form far too low an idea of Africans, generally, until we have mixed amongst them. When we penetrate some distance from the coast, we find that all the more important tribes and natives, are comparatively civilised; they are universally clad in cotton dresses of their own manufacture, often very ingeniously worked, and very beautifully dyed with the native dyes. They work in iron; and some of their native implements are not to be despised. Some nations, as the people of Bornou, wear a kind of chain armour. In many instances, they cultivate their country with considerable care. There are roads through it. They have towns with from 5,000 to 40,000 inhabitants, and they carry on a very considerable trade amongst themselves." Such a people can hardly be termed savages—notwithstanding the frequent wars, they make for the sake of prisoners to be sent coastward, and thence into slavery. This should rather be attributed to a perversion of the legitimate commercial ardour; and it is not too much to predict that, so soon as the portals of central Africa are thrown open to the expansion of European commercial principles—the curse of slave capture will cease in deference to a stronger, if not a purer principle than any yet brought to bear against it,—the principle of self-

interest. When the bare labour of a negro in his native country becomes of greater value than the sale of his body, then must the slave trade cease.

Although Africa has been hitherto spoken of as the source of vegetable fatty matters, it is, by no means, only the source of these, nor are the trees already specified, the only ones, of which cognisance has yet taken advantage for the production of this class of material. The cocoa-nut also yields a valuable oil, which is now extensively used in the stearic-candle manufactory. In the year 1829, Mr. James Soames took out a patent for separating cocoa-nut oil into its solid and liquid parts. In 1830, this patent was sold to Mr. William Wilson and Mr. Lancaster, who, trading under the name of Price and Co., brought it into operation the same year. Subsequently, Messrs. Price and Co., were obliged to establish extensive crushing-mills in Ceylon, for separating the oil from the kernel of the cocoa-nut, and these are still at work. Besides the vegetable sources of fatty material already mentioned, there exist many others, although not hitherto produced to the extent, or with the regularity, necessary to satisfy the wants of commerce. Amongst the chief of these fat yielding materials are the following:—The *Rhus succedaneum* and the *Stillingia sebifera*, both of Chinese growth—and the *Ceroxylon andicola*, of the Brazils—the substance yielded by which latter tree is more like wax than tallow.

The executive of Price's candle company has

taken great pains to collect in China commercial bulks of the Stillingia sebifera. They even secured to this end the good offers of certain Russian missionaries, but unsuccessfully. In consequence of the Chinese eating all their animal fat, the whole growth of vegetable tallow is expended at home in the manufacture of native candles.

LECTURE VIII.

ON HYDROCARBONS.

I PURPOSE to-day to call your attention to the binary compounds of hydrogen and carbon. They are extremely numerous, and present many points of great interest and importance both to the theoretical and practical chemist. They are produced in various ways, and many of them are natural products; but they all strictly belong to the domain of *organic chemistry*, inasmuch as they cannot be formed by the direct combination of their two elements, but are the results of the decomposition of substances of animal or vegetable origin.

The applications of many of these bodies to the purposes of the useful arts are very remarkable; and when I mention coal gas, india rubber, and gutta percha, as belonging to the class of hydrocarbons, you will at once admit that their general history possesses peculiar claims upon the attention of all who are interested in the progress of the chemistry of the arts.

The following table represents the *atomic composi-*

tion of some of the principal hydrocarbons which have been, or will be, adverted to in these lectures, and it exhibits many very curious points in their chemical history; it shows you the various proportions in which carbon and hydrogen combine, and it also shows you that in many of these compounds, which are perfectly distinct and dissimilar, the relative proportion of the carbon and the hydrogen is the same—namely, by weight, six to one; so that the distinctive properties of this division of the hydrocarbons are due, not to what can strictly be called *dissimilar composition*, but to dissimilar molecular constitution, and vapour-density. Take olefiant gas, terhydrocarbon, etherine, and paraffine, as instances. They are all constituted of carbon and hydrogen, *in the relative proportion of* 6 *to* 1, and consequently, if you look to the columns of the table shewing their *per centage composition*, you find that they each yield 85·7 of carbon, and 14·3 of hydrogen. But this identity of *chemical composition*, is accompanied by dissimilarity of *molecular constitution*, and consequently of *vapour-density*. Thus 1 volume of olefiant vapour includes 2 atoms of carbon and 2 of hydrogen; 1 volume of terhydrocarbon, 3 and 3; 1 volume of etherine 4 and 4; and 1 volume of paraffine (vapour), probably 10 and 10.

In this table C represents an atom of carbon, and H an atom of hydrogen, the *weights* of which atoms are to each other as six to one. The small number on the right of the capital letter indicates the

number of elementary atoms existing, or supposed to exist, in one atom of the resulting compound. Thus, *light carburetted hydrogen*, or *marsh gas*, consists of one atom of carbon in combination with two atoms of hydrogen: formyle consists of two atoms of carbon in combination with one of hydrogen, and so on.

	Atomic Composition.	Composition per cent. Carbon.	Hydrogen.
Light carburetted hydrogen .	CH_2	75·0	25·0
Formyle	C_2H	92·3	7·7
Olefiant gas: bihydrocarbon .	C_2H_2	85·7	14·3
Methyle	C_2H_3	80·0	20·0
Terhydrocarbon	C_3H_3	85·7	14·3
Acetyle	C_4H_3	88·8	11·7
Etherine: quadrihydrocarbon .	C_4H_4	85·7	14·3
Ethyle	C_4H_5	82·8	17·2
Bicarburet of hydrogen: benzole	C_6H_3	92·3	7·7
Naphtha	C_6H_5	87·8	12·2
Caoutchouc	C_8H_7	87·3	12·7
Naphthaline	$C_{10}H_4$	93·7	6.3
Camphine: camphyle . . .	$C_{10}H_8$	88·2	11·8
Paraffine	$C_{10}H_{10}$	85·7	14·3
Amyle	$C_{10}H_{11}$	84·5	15·5

There are many very important points arising out of the consideration of this table, in reference, more especially, to theoretical details; but these would be foreign to the subject of the present course of lectures, and have been amply dwelt upon on former occasions; so that I must content myself at present with a few practical remarks on the hydrocarbons generally, and

then select a few of them as illustrations of their importance in the chemical arts.

Amongst the hydrocarbons, some are *gaseous*, some *liquid*, and some *solid*; and I will bring before you olefiant gas, naphtha, and naphthaline, as illustrative specimens of the three varieties. These are all found amongst the products of the destructive distillation of coal, and have, consequently, an immediate bearing upon the details of that most interesting and gigantic manufacture.

The term *olefiant gas* has reference to the circumstance of its forming a compound once supposed to be of an *oily* nature, when acted upon by chlorine. It is an objectionable name, but, having been long in use, and invariably limited to this special hydrocarbon, it has become its usual designation. It is perhaps more properly called *bihydrocarbon*; but when the combinations of two elements are as numerous as in the present instance, nomenclature becomes inevitably hampered and difficult, and almost all the nomenclatural innovations bearing upon the hydrocarbons, have led to much greater difficulties, obscurities, barbarisms, and perplexities, than those they have attempted to replace. Witness the late lucubrations of Leopold Gmelin upon this subject, as set forth in his admirable and laborious "Handbook of Chemistry."

Olefiant gas, as I have just said, is one of the components of common coal gas, and a very valuable and important one, as contributing to the luminosity and

perfection of its flame. To obtain it in a pure form, we resort to the abstraction of water from alcohol, by the action of oil of vitriol at a high temperature. Alcohol may be theoretically represented as a compound of two atoms of olefiant gas and two atoms of water. Now if, as is going on in the apparatus before you, I pass the vapour of alcohol through boiling sulphuric acid so far diluted with water as to boil at 325°, or thereabout, the water of the alcohol is abstracted by the hot acid, and the olefiant gas escapes; in other words, under the circumstances before you, one atom of alcohol is split into two atoms of water and two atoms of olefiant gas. This diagram explains the process :—

$$\underset{\text{alcohol.}}{C_4H_6O_2} = \underset{\text{olefiant gas.}}{2(C_2H_2)} + \underset{\text{water.}}{2HO}.$$

I shall offer no apology for the frequent use of *symbols* which I venture to make in these lectures, because I know they are intelligible to the majority of my audience, and, where that is not the case, a very few hours devoted to the explanation given of them in elementary works, will remove all difficulty. Of their value in chemical illustration and discussion there can be but one opinion; they address themselves directly and forcibly through the eye to the mind, and tell a long story with admirable brevity.

Here then we have pure *olefiant gas*; it is nearly, but not quite, as heavy as atmospheric air; it has, when

duly purified by washing with water, little smell, and is very slightly taken up by water: it burns with a beautiful and bright flame; and when issuing from a proper jet, so as to give it a sufficient supply of air, its flame is quite free from smoke. Of course, when burned, it produces carbonic acid and water.

Look now at our *liquid* hydrocarbon, *naphtha;* it is one of the multifarious products of pit-coal distillation, and is usually obtained from coal tar, being one of the condensible vapours generated in the gas factory. Naphtha is also a *natural product,* and is found in considerable quantity at Baku, near Derbent, on the north west shore of the Caspian Sea; it is also met with at Monte Chiaro, near Piacenza; and at Monte Festino, near Modena; it may also be obtained from petroleum, and other varieties of so-called mineral tar. It is much lighter than water, in the proportion, namely, of about eight to ten; very limpid and colourless, when pure; and of a peculiar penetrating bituminous odour; it does not mix with water. If set fire to, it burns with a sooty smoky flame; it is a solvent of oils and resins, but is chiefly valuable from the facility with which it acts upon caoutchouc, gelatinising and dissolving that intractable material, and so facilitating, as we shall presently find, many of its most useful applications. When burned in a common lamp, naphtha produces a vast quantity of smoke, and gives an obscure flame; but when the wick is so managed as to receive a very large supply of air (as in a camphine or oil of turpentine lamp) its flame is

brighter; and it is magnificently brilliant when fed by oxygen gas. Here is such a lamp, and you see how splendid the light is. The fact is, that a very large supply of oxygen is required to burn the whole of the carbon of naphtha into carbonic acid, for by referring to the table of composition you will see that it contains nearly 88 per cent. of carbon, whereas olefiant gas contains about 86, and is greatly inferior in density to naphtha vapour; in the proportion, namely, of 14 to 21. In fact, naphtha vapour requires between three and four times as much oxygen for its perfect combustion as the same volume of olefiant gas; and produces corresponding quantities of carbonic acid and aqueous vapour.

As a specimen of a *solid* hydrocarbon I have selected this beautiful substance *naphthaline*. It also is a product of gas manufactories, and, from its extreme volatility, it sometimes produces great inconvenience by passing on with the gas into the main and branch pipes of the streets, and condensing there in such quantities as nearly to stop them up. When first obtained it is brown, but by careful sublimation assumes the colourless crystalline plates in which you here see it. It has a slight and not disagreeable odour; is a little heavier than water, unctuous to the touch, and slowly evaporates when exposed to the air; it melts at about 176°, and when inflamed throws off a large quantity of black smoke, which diffuses itself in light films of carbon through the air. It contains, in fact, nearly 94 per cent. of carbon; and if you compare the density of its vapour with that of olefiant

gas, it is in the proportion of 64 to 14; it therefore requires an enormous quantity of air for its perfect combustion, and it is impossible to burn it without smoke. This curious product has not been made use of in the arts.

I will now further illustrate the combustible peculiarities of some of these hydrocarbons, by burning them in oxygen gas. Here, for instance, is the flame of olefiant gas burning in an atmosphere of pure oxygen; its light, you observe, is diminished, and it now has a clear blue flame: whereas, if I burn naphtha, or benzole, or oil of turpentine (called in the table camphyle or camphine) in a properly constructed lamp supplied with oxygen, the light is so intense that the eye can scarcely endure it. The cause of all this I have formerly discussed, when upon the subject of *flame;* in the case of the olefiant gas, the carbon and the hydrogen are so proportioned to each other, that when burned in atmospheric air, the hydrogen forms water, and the carbon carbonic acid; and there is, consequently, no separation of solid carbon, or soot or smoke. And here I must remind you of one very essential point in respect to all these combustions—namely, that the affinity of hydrogen for oxygen, at high temperatures, exceeds that of carbon; so that the hydrogen burns *first.* The consequence is that the carbon is thrown out, and if in excess, forms soot or smoke; but if not in excess, it becomes instantaneously heated white hot in the flame of the hydrogen, and so is entirely burned into carbonic acid; and this preliminary ignition of the particles of

solid carbon is the great source of the *light* of flame. Now in naphtha, and its associates, the same thing happens when they are burned in pure oxygen gas; but in atmospheric air it is otherwise: the air does not yield a sufficient supply of oxygen to convert the whole of the precipitated carbon into carbonic acid, and hence the fuliginosity of their flames. And now, if we go to hydrocarbons still richer in carbon, such as naphthaline, we find that even whilst burning in pure oxygen, they throw off large quantities of carbon, and cannot, therefore, under any circumstances, be used as sources of light, except in a state of adequate dilution by hydrogen.

There are two or three other useful and every-day applications of these hydrocarbons, which I would just hint at, and in which they are employed to increase the luminosity of flames deficient in carbon. Let us set out with the extreme case of the flame of *pure hydrogen*, which is so dim and pale as scarcely to be visible in day-light; but which, if the gas be passed through a sponge, or other convenient tissue imbued with *naphtha*, or other volatile hydrocarbon of that class, takes up a sufficiency of its vapour to render the flame luminous, and even smoky. So, also, with respect to poor and thin coal gas, the flame of which is deficient in light, but may be rendered brilliant by passing through a gas meter containing naphtha; or, more simply, by causing it to traverse a chamber or vessel containing naphtha, in its way to the burner. Mr. George Lowe has contrived

various means of effecting this *naphthalisation* of coal gas, which involve other advantages besides the mere increase of light.

There is another of these hydrocarbons which I must advert to, as having been originally discovered and identified as a distinct compound by Mr. Faraday: he detected it, mixed with others, in the products of the destructive distillation of whale oil, which was once resorted to as a source of gas, for the purposes of illumination, under the name of *portable gas*. As it contains carbon and hydrogen, in the atomic proportions of 2 to 1, it was properly enough termed *bicarburet of hydrogen;* it subsequently received the name of *benzole*, in consequence of its having been procured by distilling a mixture of benzoic acid and quicklime. It became the subject of a very interesting discourse at one of our Friday evening meetings, by Mr. C. E. Mansfield, who pointed out its somewhat abundant existence in coal tar, or rather in the crude naphtha distilled from it; he showed the means of purifying it, and suggested a variety of useful applications of which it is susceptible as an illuminating agent; its volatility being such, that even common air, *naphthalised by benzole*, may be used as a substitute for coal gas, where proper burners are adapted to it.

A lecture on *hydrocarbons* ought to embrace a further account of the sources, composition, and uses of *coal gas;* but having lately discussed those subjects at some length, in a separate course of lectures, I shall

rest content with reminding you of the complex nature of pit-coal, and the consequent production of a variety of compounds resulting from its decomposition, exclusive of those of carbon and hydrogen, which in themselves are very numerous. Besides carbon and hydrogen, all the common varieties of pit-coal contain nitrogen and sulphur, iron, and various earthy impurities, in very variable proportions; and, accordingly, in the *purification of coal gas*, we have to abstract all sulphur compounds, which are highly mischievous ingredients, and also the *ammonia*, resulting from the combination of hydrogen and nitrogen, of which I shall speak more at large in the next lecture. All sulphur compounds are very prejudicial, as forming *sulphurous acid* when burned; and it is difficult to remove all traces of them by any of the processes of purification in common use; but as far as the worst of them, namely *sulphuretted hydrogen*, is concerned, it should never be, and indeed very rarely is, present in the gas now supplied for London consumption. Its presence is easily detected by the facility with which it blackens paper imbued with sugar of lead. Ammonia greatly deteriorates the illuminating power of coal gas, and is readily detected by good turmeric paper, the yellow of which it immediately changes to deep brown. The purified coal gas, as used for illumination, should consist of hydrocarbons only; and of these, the richer it is in olefiant gas, the better; its high illuminating power frequently, however, depends upon the presence of the vapours of some of the other

hydrocarbons, which, if it be not consumed in burners specially adapted to them, are apt to cause it to smoke.

There is, perhaps, no department of organic chemistry of higher importance than that which includes the philosophy of gas illumination; and great as its recent progress has been, it promises extension far beyond anything which it has yet attained. In many of its applications, indeed, it is still in its infancy; in others, it has merely begun to exist; but even here it promises great things. I allude chiefly to the use of gas as a substitute for the enormous and wasteful consumption of coal in kitchen fires, and in the general operations of cookery; and I have no doubt that it will ultimately come into very extensive use in our sitting-room fires. But to attain these desirable ends, and indeed for the general extension of its economical applications, several causes must co-operate, which as yet are not in a very promising state of forwardness. In the first place, we must have cheaper gas, and perhaps derive it from other sources than coal. Then, the means of its purification, distribution, and combustion, must be improved; and the obstinacy of architects must be overcome, who set their faces against all rational modes of heating, lighting, and ventilating, in which philosophical principles are involved, and consequently leave all those matters open to the unrestricted incursions of empirics of all denominations.

To give you some idea of the gigantic operations of the gas manufacture, let me recall your attention to

what is at this moment going on in London only; and then, by recollecting that in all the large towns of the kingdom similar establishments are at work, you will at once see, that in a philosophical, pecuniary, and sanitary sense, we are dealing with a subject of extraordinary dimensions. It appears from the *data* which I have elsewhere adduced, that there are, at the present time (March, 1852), about *fifteen gas companies* supplying London and its immediate precincts; that they have about *twenty-one stations or factories;* that their annual consumption of *coals* exceeds *five hundred and seventy thousand tons*, yielding *fifty-two thousand million cubic feet of gas*. And as regards daily consumption, this of course fluctuates greatly with the seasons; but taking it at its maximum, on the shortest day, it exceeds twenty-one million cubic feet; and requires for its production about two thousand four hundred tons of coals, assuming the average produce of purified gas of one ton of coal, to be about nine thousand cubic feet. On these occasions, there are not less than six thousand red-hot retorts in constant operation. The extent of gas main in London, the statistics of the several factories, the number of workmen and labourers employed, the contents and number of the gasometers, and various similar details, I must pass over as irrelevant here, but not as undeserving serious consideration. It is remarkable that, considering the *theoretical* dangers of gas manufacture, and more especially in relation to the many million cubic feet of gas in constant store, which only requires due admixture

with air to render it a violently explosive compound, scarcely a single accident of any magnitude has ever occurred in gas factories, which stand, with strange impunity, in the midst of crowded parts of the town, some of the single gas-holders containing not less than a million cubic feet of inflammable matter.

I must now revert to two other products belonging to the class of hydrocarbons, and which, from their numerous and useful applications in the arts, have of late acquired great interest and importance, namely, *Caoutchouc* (or *India Rubber*), and *Gutta Percha.*

Caoutchouc is sometimes called *gum-elastic*, but it has none of the characters of a gum, being perfectly insoluble in water; nor is it a resin, for it is insoluble in alcohol; but ether, which has been washed, so as to deprive it of alcohol, dissolves it, with the exception of impurities, and leaves it, on evaporation, in its perfectly elastic state; it also dissolves in chloroform, and in sulphuret of carbon, and in some of the essential oils; but its most common and useful solvents are rectified naphtha, and oil of turpentine; it swells up in these, forming a bulky soft mass, which is taken up by the addition of a further quantity of the solvent, and especially by the help of heat. When these solutions are spread upon a surface, in the manner of a varnish, the greater part of the solvent soon evaporates, especially in a warm atmosphere, and an elastic layer or film of the caoutchouc remains. Chlorine, and the concen-

trated acids and alkalies, have very little action on caoutchouc in the cold.

This substance came first into notice about the beginning of the last century, moulded into the shape of bottles and animals. It was sold as high as a guinea the ounce, and used for rubbing out pencil marks; but scarcely anything was known of its history, except that it came from America, till De la Condamine sent an account of it to the French Academy in 1736, describing it as the inspissated juice of a tree, called by the natives *hevee.* In the year 1751, Frisnau discovered the same tree in Cayenne. It is now known to be the produce of several trees growing in South America and in the East Indies. It exudes from fissures and wounds of the trees, in the form of a milky juice, which, exposed to air, soon forms the elastic deposit. It is very inflammable, burning with a dense smoky flame. It burns brilliantly in oxygen gas, but even then throws off abundant flakes of unburned carbon. When subjected to distillation in close vessels, it yields an oily liquid which has a singularly disagreeable and penetrating greasy smell, and appears to be a mixture of several hydrocarbons, one of which predominates, and has been termed *caoutchine*; it is represented by the formula $C_{10}H_8$, and is therefore isomeric with *camphine;* or, according to other authorities, its composition is $C_{10}H_{10}$, which is isomeric with olefiant gas, etherine, &c. The oily hydrocarbons thus obtainable amount to as much as 85 per cent. of the

original rubber, and as the latter readily dissolves in them, they might perhaps be used as substitutes for other solvents, were it not for their abominable odour.

The first person who applied India rubber largely in manufactures, was Mr. Charles Macintosh, of Glasgow; and the water-proof tissues which he made were well known by his name; but they had one insuperable objection, namely, that they became rigid in cold weather, and afterwards with difficulty resumed their pliability; so that when a so-called *Macintosh* had been suspended for some time upon a peg, or folded up in a wardrobe, it frequently became so stiff and intractable as to be nearly useless; and this, together with some other objectionable points about them, threatened to throw the manufacture into disuse. But about the year 1843, Mr. Thomas Hancock, of London, made a very curious and important discovery in respect to caoutchouc, which has given an entirely new aspect to almost all the manufactures dependent upon it; and by which its properties are so modified and improved, in respect to the great majority of its uses, as to constitute it, as it were, a new material. In this altered condition, it is now known under the name of *Vulcanised India Rubber*, and as the whole process is a very remarkable one, I will endeavour to show you the various steps by which it is effected. The abundance of articles of all kinds, which are upon the table before me, will speak for themselves as to the utility and importance of this remarkable invention. I

am indebted to Mr. Hancock, and generally to the firm of Messrs. Macintosh and Company, of Manchester, for the specimens before you. I have visited their factory and examined the numerous operations carried on there, in all their particulars, so that although my time obliges me to be very brief in the details I now wish to illustrate, I shall be happy, after lecture, to give any further information upon them which may be required.

India rubber, as imported, generally includes mixed impurities of different kinds, which are got rid of by tearing it up into shreds, in a stream of water; it is then transferred to a machine called a *masticator*, where it is severely pinched and kneaded, till it forms a kind of mass or magma, which may be compressed into blocks, cut into sheets or threads, or rolled out into layers as thin or thick as we please; but all these, and similar operations, leave the rubber with its original objectionable qualities, namely, its clamminess, its tendency to stiffen and harden, and consequently to lose its elasticity by cold; to be readily softened and decomposed by heat; and to be rendered soft and, as it were, rotten by grease and oils. As to the clammy adhesiveness of India rubber, Mr. Hancock gets rid of that by thoroughly and completely blending it with a quantity of finely-powdered French chalk, or silicate of magnesia, the well-known soft, silky feel of which, is thus imparted to the rubber.

The other objectionable properties are subdued by the extraordinary influence of *sulphur;* and it is to its

operation that I particularly wish to direct your attention. Sulphur is, in any convenient way, in the first instance, *mixed* or *blended* with the rubber; as by solution, or rolling, or in the masticator, or dipping into melted sulphur. I have here a mass of India rubber which contains about ten per cent. of flowers of sulphur well mixed or blended with it; but, as yet, the common properties of the rubber are unaffected. If, however, we now expose this mixture of rubber and sulphur for a due time to a high temperature, which may vary with circumstances, a change ensues. I here heat it to about 300°, and find the characters of the rubber gradually alter. Ultimately it will be *changed* or *vulcanised;* that is, it will have acquired the new characters and properties to which I have briefly alluded. Its elasticity is not only increased, but is now not affected by change of temperature; that is, it is not in the least hardened or altered by any degree of cold; it retains its perfect elasticity at the lowest temperatures; and what is perhaps even still more remarkable, when heated, it does not fuse and become clammy and viscid, but remains unchanged at all temperatures short of its absolute decomposition; ether, oil of turpentine, naphtha, and its other solvents, now barely affect it; and oil and grease no longer penetrate and soften it. Such are the *new properties* conferred upon the rubber by the joint operation of sulphur and heat: it is now said to be *vulcanised.* But the most curious part of this story remains to be told, and arises out of this question, namely, What

quantity of sulphur is required to be thus combined with the rubber for the purpose of *changing* it? Certainly not more than one or two per cent.; for if by any of the solvents of sulphur, as for instance by the alkalies, I remove all excess of sulphur, I in no way affect the new properties; but yet further, if I take steps still to remove more of the sulphur, and ultimately leave the rubber apparently quite free from it, I still find that it retains all those peculiarities which I have enumerated as characterising vulcanisation. May we not therefore conclude that, under the influence of sulphur and heat, the India rubber acquires its new and distinct properties, not by actual chemical combination with a minute portion of sulphur, but by the assumption of a new *molecular condition;* that, like phosphorus, it has assumed an *allotropic state.* In short, these allotropic conditions of bodies are daily becoming more worthy of remark and inquiry; thus, it is not unlikely that *steel* even may be an *allotropic condition of iron,* produced under the influence of carbon upon iron at high temperatures; for the quantity of carbon in the finest steel does not reach *one per cent.*, and there are cases in which the metal is *nearly* pure to all chemical tests, and yet retains the leading characters belonging to steel.

My time will allow me to say very little upon the subject of *gutta percha.* This valuable product is the inspissated juice of a tree belonging to the natural family *Sapotaceæ,* and of which a representation is subjoined.

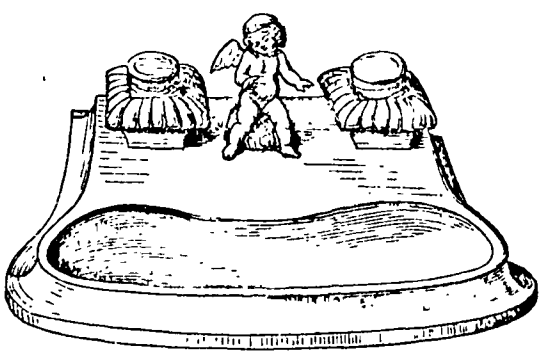
BRANCH OF GUTTA PERCHA TREE.

All our supplies of this valuable hydro-carbon have been hitherto procured from the island of Singapore, and the neighbouring parts of the Malayan peninsula, regions of the globe which have been known to and occupied in turn by the Portugese, Dutch, and English for a period of three centuries and a half, during which, there is every reason to believe, the applications of this substance were constantly made by the natives themselves; yet, until the year 1842, remained to every European nation unknown.

In that year, Dr. Montgomerie observed in the hands of a native woodman, a parang, or wood-chopper, the handle of which was composed of a singular looking substance. This excited his curiosity. "I questioned the workman," said he, "in whose possession I saw it, and heard, that the material from which it was framed could be moulded into any form by dipping it into boiling hot water until it was heated through, when it became plastic as clay, regaining when cold its original hardness and rigidity." Directing his inquiries further, Dr. Montgomerie ascertained, that like caoutchouc the substance exuded from a forest tree; and having procured several specimens, he forwarded them to the Society of Arts, which awarded their gold medal to the Doctor for his very valuable discovery.

No sooner were the peculiarities of this remarkable substance brought before the notice of scientific men, than discovery after discovery rapidly followed, each having for its object the application of the

new hydro-carbon to some important purpose. Soluble, like caoutchouc, in liquid hydro-carbons, gutta percha was speedily applied to the formation of water-proof tissues; whilst its extreme tenacity suggested its employment as a substitute for leather; and its ready quality of incorporating with other bodies, rendered it capable of assuming, on the one hand, all the hardness of wood,—on the other, of simulating any desired amount of impressible softness.



INKSTAND IN GUTTA PERCHA.

The credit of having discovered gutta percha very nearly fell to the lot of Mr. William Lobb, a gentleman who had been sent to Eastern Asia by Messrs. Veitch, the enterprising florists of Exeter, in the year 1842–3. Indeed, perhaps it is an open question whether Mr. Lobb became acquainted with gutta percha concurrently with or immediately after Dr. Montgomerie; the latter, however, first brought a specimen of gutta

percha to England, and made known its numerous properties.

One of the latest applications of gutta percha as a substitute for wood, is in the formation of cog-wheels. Only one kind of wood, the hornbeam, answers this purpose satisfactorily; and this, no more than any other wood, prevents the disagreeable rattling which such cog-wheels make when in motion. Gutta percha, incorporated with a due amount of saw-dust, is an admirable substitute. Not only is it said to be equally effective with the hornbeam, but there is no longer any noise, wheels having cogs of this material being comparatively silent when in motion.

Perhaps the most important of all the purposes to which gutta percha has hitherto been applied, is as an envelope to the wires of the electric telegraph. Before the employment of gutta percha, these wires were insulated imperfectly by the troublesome operation of covering them with cotton twist. Even as limited to terrestrial communication, this plan of insulation was very imperfect, and it never could have served the purpose of submarine electric communication. Gutta percha forms a very admirable material for coating these wires, combining the good qualities of a very imperfect conductor of electricity with great facility of being superimposed on the wire.

When used for this purpose, however, the gutta percha requires to be totally free from particles of wood and saw-dust. To accomplish this complete

purification is not easy. It involves a very extraordinary kind of filtration, the softened gutta percha being forced by hydrostatic pressure through minute orifices, drilled in a thick piece of wrought iron, constituting one of the ends or terminal plates of a cylinder, through the other end of which works the compressing piston.

The purification of gutta percha in its general principles, is the same as with caoutchouc; consisting in first tearing the raw material into shreds, then kneading those shreds, whilst surrounded by water. The kneading operation being conducted by the aid of very powerful machinery, much heat is developed, reducing the material to a pasty condition, whilst the surrounding water dissolves out and removes the associated impurities.

The difference of coherence between the particles of India rubber and those of gutta percha, causes a slight but very important difference of result at one period of the manufacturing operation. Gutta percha admits of being torn into much finer shreds than India rubber, and these shreds being allowed to remain for a short time in water before the commencement of kneading, much of the woody dust and spiculæ with which the native gutta percha is mingled, absorbs water, becomes specifically heavier than water, and sinks; whereas, the shreds of gutta percha continue to swim. Separation of woody dust could not be effected to a similar extent from India rubber, nor, indeed, is the operation required

on that substance, which seldom contains that kind of impurity.

LION'S HEAD IN GUTTA PERCHA.

It is much to be regretted that the operation of procuring gutta percha is often fatal to the tree

which yields it, even when obtained by cutting gashes in the living stem. During the first period of gutta percha commerce, the unnecessarily destructive plan of felling the tree was had recourse to, and in this manner all the original regions of Singapore, from which the gutta percha was first exported, soon became exhausted. At present, the supply from Singapore has largely fallen off. Borneo, however, is said to contain forests of great extent, in which gutta-percha trees are the chief growth. To Borneo, therefore, it would seem that commerce must, in future, look for a supply of this now indispensable material.

LECTURE IX.

ON NITROGENIFEROUS, OR AZOTISED SUBSTANCES.

THERE are many of the chemical arts and manufactures in which azotic or nitrogeniferous substances are concerned, such as *nitric acid* and the *nitrates; ammonia* and its compounds; and *cyanogen* and its derivatives. Nitrogen is also an essential element in all *food of nutrition*, properly so called; or, in other words, it is an essential element of the blood, and of the greater number of animal tissues, and must consequently be contained in all food which is to replace the waste of such matters, whether in graminivorous or carnivorous animals; nitrogen, therefore, must be contained in all those vegetable substances upon which cattle feed; and it is under this aspect that its presence in manures, and other ingredients of the soil which are to furnish nutriment to the various vegetable tribes upon which the graminivora, or rather the *phytivora*, live, becomes a question of deep interest to the agriculturalist and farmer; for although there is abundance of nitrogen in the atmosphere, neither plants nor animals can derive it

directly from that source. Plants appear capable of assimilating it, to a certain extent, in the state of *ammonia*,—combined, that is, with hydrogen; but before it can be assimilated by animals, it must have passed into some of those more complex arrangements, which, under the names of glutine, albumine, and legumine, are found in the juices of vegetables. These are inquiries, however, the details of which belong to another and distinct field of chemistry.

I purpose to-day, first, to bring before you some of the general properties of nitrogen, and then to consider a few of such of its combinations as are concerned in certain arts and manufactures. Let me, therefore, in the first instance, show you the peculiarities of nitrogen in its isolated state. It is a permanently elastic gas—a little lighter than atmospheric air, but fourteen times heavier than hydrogen; it has neither smell, taste, nor colour; it is not absorbable by water, and neither supports combustion nor respiration—all burning bodies are immediately extinguished when plunged into this gas, and so is animal life: it appears to kill, not by any direct chemical action upon the blood, as is the case with almost all other noxious gases, but simply by the exclusion of oxygen, and preventing the throwing off of carbonic acid; so that animals are rather stifled by nitrogen, as they are by suffocation or drowning, than absolutely poisoned. Now, from all these illustrations it will be obvious that the characters of nitrogen are pre-eminently of a negative description; it appears as a

very *indifferent* body. Not so, however, when in chemical combination; for nearly all its compounds are as pre-eminently active and energetic; powerful acids, acrid alkalies, intense poisons, violent detonators, are amongst them. I have already mentioned nitric acid, ammonia, and cyanogen as belonging to this class; they are *binary* compounds of nitrogen: all the most dangerous fulminators contain it as one of their essential elements; gunpowder cannot be made without it; in short, whether we look at nitrogen under those simpler forms of combination, which, to a certain extent, may be commanded by art, or under those more complicated relations which can only be called into existence by vital functions, we find its chemical history full of instructive and important details.

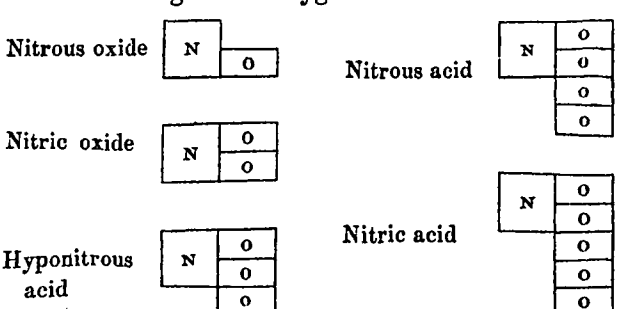
The atomic weight or equivalent of nitrogen, is 14 (in reference to hydrogen as 1), and the principal combinations of it, which I now wish to show you, are, in the first place, those which it forms with *oxygen* (and which are not less than 5 in number); and then, those which it forms with hydrogen, with carbon, with chlorine, and with iodine. Here is a diagram illustrative of the combinations of nitrogen with oxygen. I have more than once appealed to it as admirably illustrating that part of the theory of chemical combination which teaches us, that where one body combines with another in more than one proportion, the second, third, &c. proportions may always be represented as simple multiples of the first: this is indeed a necessary consequence of the atomic

theory. Now, look at the combinations of nitrogen with oxygen under this aspect:—

TABLE OF THE COMBINATIONS OF NITROGEN WITH OXYGEN.

	Symbol.	Number of the atoms or equivalents of nitrogen and oxygen.	Weights of the atoms or equivalents of nitrogen and oxygen.		Atomic weight or equivalent of the compound.
		N O	N	O	
Nitrous oxide .	NO	1+1	14	8	22
Nitric oxide .	NO_2	1+2	14	16	30
Hyponitrous acid	NO_3	1+3	14	24	38
Nitrous acid .	NO_4	1+4	14	32	46
Nitric acid .	NO_5	1+5	14	40	54

This table, you will observe, represents the weights, not the volumes of the respective elements and their combinations; but the simple ratio which the weights bear to each other, involves an equally simple law in respect of combining *volumes*. The relative *densities* of nitrogen and oxygen are to each other as 14 to 16; so that the *volumes* of the constituents of the above compounds of nitrogen and oxygen will stand as follows:—

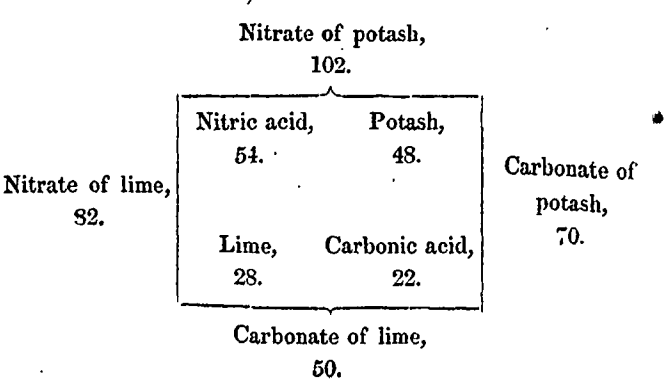


Here the volumes are 2 and 1; 2 and 2; 2 and 3; 2 and 4; and 2 and 5.

Now, as far as the chemistry of the arts is concerned, I shall have almost exclusively to mention *nitric acid*, amongst the above compounds; but the others frequently manifest themselves in various operations in which oxygen is abstracted from nitric acid; thus, the *red fuming acids* are mixtures of nitric with nitrous and hyponitrous acids; they may also contain nitric oxide; and this latter, by the abstraction of an atom of oxygen, becomes the source of nitrous oxide, a gaseous body, the curious properties of which, when respired, were discovered by Sir Humphry Davy, who was bold enough to breathe it, when he experienced its singular effects in producing symptoms somewhat resembling intoxication, in which merriment usually prevails, and which has led to the popular term of *laughing gas*.

Let us now consider the sources and properties of *nitric acid*. The commercial demands for this acid are almost exclusively supplied by the decomposition of *nitrate of potash* and *nitrate of soda;* two salts which are native products chiefly of India and America. They have also, at different times, been more or less abundantly obtained by certain artificial operations, as in what have been termed *nitre-beds;* that is, mixtures of decomposing organic matters with alkaline bodies. In India, the nitrate of potash is contained in certain soils, which, when lixiviated, yield the salt in an impure state; it is, however, easily purified by crystallisation, forming beautiful prismatic crystals, soluble in between 3 and 4 parts of water, at the temperature of 60 degrees; of a cooling and peculiar taste.

Nitre-beds, for the artificial production of this salt, were at one time common on the continent of Europe, and were made by mixing all kinds of animal refuse with old mortar, and other calcareous matters, and watering them, from time to time, with the richest sewage that could be obtained. In this way *nitrate of lime* was formed, a solution of which was obtained by lixiviating the rubbish. This solution was then mixed with one of carbonate of potash, or wood-ashes, and the results were carbonate of lime thrown down, and nitrate of potash remaining in solution. This diagram shows you the change and the requisite weights of the salts to produce it; from which it appears, that 82 pounds of nitrate of lime (composed of 54 of nitric acid and 28 of lime), when mixed with 70 pounds of carbonate of potash (composed of 48 potash and 22 carbonic acid), yield 102 pounds of nitrate of potash (composed of 54 nitric acid and 48 potash), and 50 pounds of carbonate of lime (composed of 28 of lime and 22 carbonic acid).



Exudations containing nitrate of potash are not uncommon on new walls, where it appears to be connected with the decomposition of animal matter contained in the mortar or cement. Long ago, Glauber showed, that a vault plastered over with a mixture of lime, wood-ashes, and cow-dung, soon becomes covered with an efflorescence of nitre, and that after some months the materials yield it in considerable quantity. It is this frequent appearance of nitre as an efflorescence upon soils, walls, caverns, and so forth, that led to its being called *sal petræ* or *saltpetre*.

You will observe, by the frequent mention which I have made of the presence of *animal matter* in nitre soils, how the history of nitric compounds is associated with the chemistry of organic bodies; but this will presently appear more obvious when the subject of *ammonia* is more immediately before you.

Nitrate of Soda, another source of nitric acid, is the *cubic nitre* of the older chemists; it crystallises in rhomboids, and is very soluble in water. In Peru, and elsewhere, I believe, in South America, it forms strata in alluvial soils, sometimes many miles in extent. Being somewhat cheaper than nitre, and not fit for the manufacture of gunpowder, it is a common source of nitric acid; it has also been a good deal used as a manure, but with doubtful success.

To obtain *nitric acid*, nitrate of potash, or nitrate of soda—and the salts ought to be *pure*—are distilled with somewhat more than half their weight of commercial

sulphuric acid, or, as it is more commonly called, *oil of vitriol;* the result is, that the nitric acid of the salt, combined with the water of the oil of vitriol, passes over in the form of liquid nitric acid, or *aqua fortis;* and sulphate of potash, or sulphate of soda, as the case may be, remains in the retort or still.

Nitric acid, in its dry and anhydrous state, is a white crystalline solid; it is not used, and is indeed scarcely known in this state, but is always used in the arts in combination with water; so that what is usually called *nitric acid,* is a dense acid liquor, extremely sour and corrosive, and very intense in its action upon the greater number of inflammable bodies, to which it imparts oxygen; sometimes it has a yellow, brown, or bluish green colour, and emits yellow fumes, from the presence of nitrous or hyponitrous acid, or even of nitric oxide. The oxygen in this acid is not only very large in quantity, but is held by a comparatively feeble affinity, so that it is one of the readiest and most powerful oxidising agents of the chemical laboratory; hence, also, the salts which contain it, and which are called *nitrates,* are powerful supporters of combustion. I have already observed that nitric acid, in its most concentrated liquid form, is a compound of the dry acid and water, in the proportion of from 75 to 80 parts of acid, to 25 or 20 of water; the dry acid itself, as it exists in the nitrates above adverted to, being a compound of 74 parts *per cent.* of oxygen, and 26 of nitrogen.

To give you an idea of the intense chemical powers

of nitric acid as an oxidising and decomposing agent, observe the violent action which ensues when I pour it upon copper leaf, or upon zinc foil, or upon filings of iron or of tin; it almost amounts to an explosion. Volumes of red fumes, consisting of the other compounds of nitrogen and oxygen, are evolved, and the metals are instantaneously converted into oxides, the greater number of which are soluble in the acid, for nearly all the nitrates are very soluble. Here I drop some of the strong acid upon a piece of parchment; it instantly shrivels up, and both it and the acid are decomposed. Its action upon phosphorus, aided by heat, is attended by violent inflammation; so, also, intense action, often accompanied by ignition, attends its action upon several of the essential oils. When dropped upon the skin it stains it of a permanent yellow colour, and, if left there, acts as a caustic, decomposing and dissolving the flesh. It also stains silk and wool indelibly yellow, and then goes on entirely to destroy their texture. But when certain vegetable fibres are dipped into it, and more especially cotton and linen, a *combination* sometimes ensues, as I have shown in a former lecture, when dealing with that very extraordinary and dangerous compound, *gun cotton.*

You may imagine, from what you have seen, that nitric acid is applicable to many purposes of the arts: it is especially subservient in the preparations used by dyers and calico-printers; in the manufacture of oxalic acid; in various pharmaceutical preparations; and more

especially in the analytical processes of the chemical laboratory. The surgeon sometimes uses it as an energetic caustic; and in the bite of rabid animals, there is every reason to believe that, if quickly and effectually applied to the wound, it would destroy the poison, and prevent its consequences.

But the great part played by nitric acid in the arts, is as a constituent of *gunpowder;* as an ingredient, namely, in nitre. Gunpowder is an intimate mixture of about

78	parts	of nitrate of potash.
12	„	charcoal.
10	„	sulphur.
100		

When the temperature of gunpowder is sufficiently elevated by the contact of an ignited body, a very rapid combustion of the whole mass ensues, especially if it be well prepared and duly granulated; the violence of the explosion depending upon the sudden production of gaseous matter and of intense heat, resulting from the mutual action of the combustibles, and the condensed and, as it were, solid oxygen, of the nitre. The principal gases thus suddenly extricated are carbonic oxide, carbonic acid, nitrogen, and sulphurous acid; sulphuret of potassium, with a little carbonate and sulphate of potash, is the principal residue. Considering the results of the combustion of the powder, and the very high temperature at which the gaseous products are evolved,

we may, I think, estimate the volume of the evolved gases at about 2,000 times that of the powder employed. The chief use of the sulphur is to increase the combustibility of the powder, in consequence of the comparatively low temperature at which sulphur takes fire; and the granulated state increases its explosive force and rapidity of combustion, the charge being sufficiently porous to admit of the flame penetrating it, so as to kindle every grain nearly at the same instant; and we find, accordingly, that *meal powder*, as it is called, burns more slowly than that which is granulated; and that in a compressed state, or mass, as before it is broken up for granulation, or as rammed tight into a case, its combustion is still more gradual.

But although the combustion of gunpowder is very rapid, it is by no means *instantaneous;* for if such were the case, scarcely anything could resist its power; and its explosion would then more resemble that of some of those extraordinary compounds which I shall presently have to advert to, and which, if substituted for gunpowder, would burst the gun, without propelling the ball.

But time reminds me that I must pass on to the other nitrogeniferous compounds; and the next which I shall bring before you is *ammonia*, a compound, namely, of *nitrogen with hydrogen*. As is the case with nitrogen and oxygen, nitrogen and hydrogen, when merely mixed, exhibit no tendency to combine; in order to effect their chemical union, they must be subjected to

each other under certain peculiar conditions; and one of these is attained by causing them to be simultaneously evolved from some of their compounds; or presented to each other, as is frequently said, in their *nascent state*. There are, for instance, very many organic products which contain nitrogen and hydrogen; and many among those, which, *when heated*, yield ammonia. They do not contain ammonia ready formed; but, under the influence of heat, their elementary nitrogen and hydrogen combine to form it. A feather, for instance, when burned, yields, among other products, a portion of ammonia; and you perceive the odour of ammonia in such cases very evidently; or, you may detect it more decidedly by the test of turmeric paper, the bright yellow colour of which is changed to brown, when held over the fumes of the burning feather; a change dependent upon the evolution of ammonia. Here is another test of its presence: a glass rod which has been dipped into hydrochloric acid; I hold it near the feather, and you presently see a white smoke arising from it. Now, this smoke is sal-ammoniac, or hydrochlorate of ammonia, and is produced by the union of the vapour of the acid with the ammonia which is mixed with the fumes arising from the feather. Here, then, we not only have a test of the presence of ammonia, but we learn that it is an *alkali*; for substances which act upon turmeric and certain other vegetable yellows, and turn them to brown, as you have just seen, are said to be *alkaline*. Ammonia, therefore, is frequently called *volatile alkali*. If,

instead of the feather, I had burned a piece of bone or of horn, I should have had the same effects from the same cause; hence one of the commonest compounds of ammonia is known as *spirit of hartshorn*, having been long ago procured by the destructive distillation of hartshorn shavings; for which, however, any kind of bone or horn is now substituted; and in this way ammonia is often abundantly obtained. And now you will see how it is that ammonia is formed in our *gas factories*, by the destructive distillation of common coal, which, as I have shown you, includes nitrogen and hydrogen amongst its elements; and, consequently, when heated or distilled in the gas retorts, yields, among a great many other things, a certain quantity of ammonia.

The destructive distillation, then, of *organic products containing nitrogen* (for they all contain hydrogen), is one of the leading sources whence the commercial demands for ammonia and its compounds are supplied. But by these processes the ammonia which I obtain is anything but *pure*. Let us now see how we are to obtain it free from all other matters, and what are its characteristic properties.

When hydrochlorate of ammonia and quicklime, both of which are perfectly inodorous, are well mixed together, the pungent odour of ammonia is immediately perceptible; and if they now be gently heated in a retort, gaseous ammonia is abundantly evolved; but, as it is very soluble, I cannot collect it over water, as is the case with most other gases, but must resort to

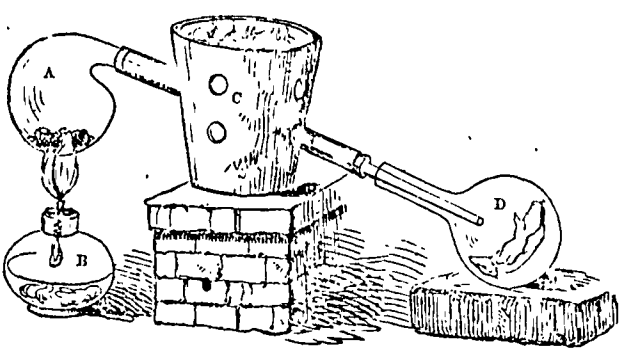
mercury for the purpose of retaining it; or, if I am not very particular as to the entire absence of atmospheric air, I may collect it by *displacement*, as it is called; that is, as it is much lighter than atmospheric air, the gaseous ammonia will rise into a dry glass jar held over the tube from which it issues, and so expel the common air, and at length fill the jar.

Gaseous ammonia is very pungent and acrid, and of course unrespirable; it is powerfully *alkaline;* that is, it reddens the yellow of turmeric, converts certain vegetable blues to green, and saturates the acids, producing *ammoniacal salts*, which are easily recognised by their evolving ammonia when triturated with potash, soda, or lime. The specific gravity of air, compared with that of ammonia, is about as 10 to 6. It extinguishes flame, but may itself be burned when duly mixed with oxygen gas.

Ammonia, or the *volatile alkali*, furnishes a good illustration of the new properties which bodies acquire by *combination;* it consists of 1 volume of nitrogen and 3 volumes of hydrogen, which are condensed by union into 2 volumes of gaseous ammonia; or of about 82 parts of nitrogen and 18 of hydrogen, by weight. Now its elements are without smell or taste, have no action on vegetable colours, are not soluble in water; how opposite are these inert characters, to the intense activity and acrimony of ammonia, and of which water dissolves nearly 700 times its volume. It is in this state of *aqueous solution*, that ammonia is always used

as a chemical agent; it partakes of the energetic characters of the gas.

The elements of ammonia are held together by but a feeble degree of affinity, for if it be passed through a white-hot tube, it is decomposed, and resolved into a mixture of nitrogen and hydrogen gases. But this experiment may be rendered more striking, and highly instructive, by passing the ammonia through a red-hot tube containing peroxide of manganese; in which case, the oxygen, gradually given off, combines both with the nitrogen and the hydrogen of the ammonia, and nitric or nitrous acid, and water, are formed; so that here, by what may be termed the *combustion* of the ammonia, the alkali is changed into an acid. The following diagram will render the form of this experiment obvious.



A is a retort containing quicklime and sal-ammoniac, heated by the spirit lamp B. The porcelain tube connected with the retort, and containing black oxide of manganese, is duly heated to redness in the furnace C,

and the *acid* fumes are manifested in the glass globe or receiver D, which may contain a few slips of blue litmus paper.

Now it would seem that a change analogous to that exhibited in this experiment, is in some cases *spontaneously* effected—as when ammonia is slowly evolved from decaying or putrefying animal substances, and where, under the influence of moist air, and in the presence of some powerful base, the nitrogen is acidified. Such seem to be the changes which take place in the *nitre-beds* before alluded to; and in this way we may account for the large proportion of nitrate of lime contained in the drainage water of soils, abounding in decaying organic matters rich in nitrogen. The water of the shallow wells in large towns almost always contains *nitrates*, and that pumped up in churchyards is more especially rich in them.

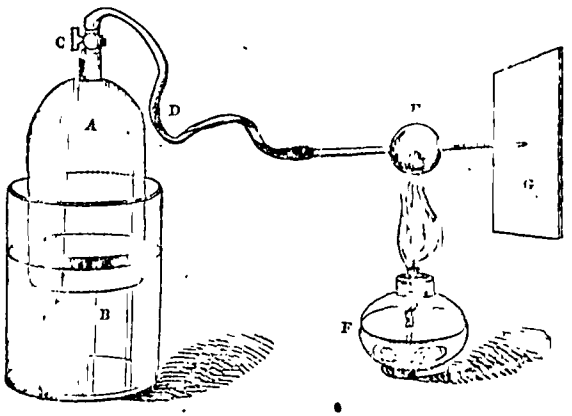
I shall dismiss this subject, by adverting to a very curious case of the *formation* of ammonia, for which we are indebted to Dr. Hare. Here is a small glass gasometer containing a mixture of 2 volumes of nitric oxide gas, and 5 volumes of hydrogen; connected with its exit tube is a glass bulb, containing a little spongy platinum, or some asbestos, which, having been imbued with chloride of platinum, and then heated red hot, has become plated with the metal. Now, if by opening the stop-cock of the gas-holder, I allow a little of its contents to pass through the tubes connected with it, and escape at the further end, the nitric oxide present will com-

bine with the oxygen of the air, and immediately generate copious fumes of *nitrous acid*, rendered apparent by their orange colour, and by their intense reddening action upon a piece of blue litmus paper, held before the jet. But if I now apply heat to the platinised asbestos, by means of the flame of a spirit lamp, and having so done, again open the stop-cock, and allow the mixture of hydrogen and nitric oxide gas to pass slowly out, a very different result will be obtained; and instead of *acid*, I shall have *alkaline* fumes passing out at the jet, which will restore the blue colour to the reddened litmus; or which, if I use turmeric paper, will immediately change it to brown. Now here, under the influence of the heated platinum, I find that the hydrogen decomposes the nitric oxide, forming ammonia with its nitrogen, and water with its oxygen; so that, in fact, *ammonia* and *steam* are the products of this curious experiment; and we command the production either of alkali or of acid, according as heat is or is not applied to the finely divided platinum over which the gases are made to pass. The following diagram will give a notion of the arrangement of the apparatus.

A is the gasholder, or bell-glass, floating in water contained in the jar B; C, the stop-cock, communicating with the flexible tube, D, and the glass tube and bulb, E; F, the spirit lamp; and G, the litmus or turmeric paper.

The *modus operandi* of the heated spongy platinum, or of the platinised surface of the asbestos, under the influence of which the hydrogen and nitrogen combine

to form ammonia, is still unexplained. You have seen the same influence effective in producing the combina-



tion of oxygen and hydrogen gases, so as to form water. It would seem as if certain gases, by some peculiar attractive force, were brought into such a state of condensation upon the metallic film, as to induce them to combine; affinities being then displayed, which are dormant amongst the particles whilst gaseous.

There are many other curious facts connected with the formation and evolution of ammonia besides those I have touched upon; but I must pass these over, and I do so with the less regret, having formerly brought the whole subject fully before you.

You will recollect the important bearings of these inquiries upon *chemical physiology*, and more especially upon the *chemistry of agriculture*. I have brought before you evidence showing that animals derive the

whole, or nearly the whole, of their nitrogen from their food; and, consequently, originally from the vegetable creation—from the nitrogeniferous compounds contained in the grasses and herbs upon which they live. Now, as far as *vegetable nutrition* is concerned, it is more than probable that the whole of the nitrogen of that kingdom of nature is conveyed into the plant, in the form of *ammonia;* that this supply is maintained by the decay of organic matter, by manures, by ammoniacal salts, and by the presence of carbonate of ammonia in rain water and in the atmosphere;—in very minute quantities of course, for the nature of ammonia and its solubility would prevent anything like accumulation; but still, there it is, and its presence seems essential. Liebig, Johnston, and other chemical and agricultural physiologists, have given the details upon which these speculations rest, and they are in every way important; they bring before us curious illustrations of the mutual dependence of plants and animals; showing the accumulative functions of the former, and the destructive functions of the latter. The food of the vegetable kingdom is principally administered to it in the form of water, carbonic acid, and ammonia; materials furnished by the atmosphere on the one hand, and the soil on the other. These substances are first decomposed, and then recompounded in the wonderful organisation of the plant; equally by the lowliest and most insignificant herb, and by the loftiest and most gigantic tree; all at work in the same direction. Now the *ultimate elements* of water,

carbonic acid, and ammonia, are carbon, hydrogen, oxygen, and nitrogen, which, together with certain substances derived exclusively from the soil, amongst which phosphorus and sulphur, potash and soda, lime and magnesia, chlorine and iron, are the most essential, are elaborated by the vegetable organism into the *proximate principles*, or in other words, into the *food* of animals; namely, into all the modifications of the so-called *proteine* compounds, in which nitrogen is essential; and into sugar, gum, starch, and fatty matters, which are ternary compounds of carbon, hydrogen, and oxygen, and so far, therefore, independent of nitrogen.

But now consider what is going on in the *animal system*: there, the several proximate principles compounded in the vegetable organism, are successively resolved into more simple forms, and ultimately into the very carbonic acid, ammonia, water, and inorganic products upon which plants feed. Carbonic acid and water are copiously thrown off by the lungs; the kidneys secrete urea, which soon resolves itself into carbonate of ammonia; and the inorganic matters are found in the excrementitious offal. In the living animal these changes are essential to the continuance of the vital functions, and the vital functions to them; but similar changes go on after death; the whole being a species of slow combustion, contributing to the heat of the living animal, and to the decay of the dead; so that the fabric, deprived of its reproductive requisites,

and stripped of the mysterious attributes conferred upon it by *life*, slowly vanishes into those gaseous and solid products which I have enumerated.

The principal *salts of ammonia* which are known in commerce, or used in the arts, are the *sulphate, hydrochlorate*, and *carbonate;* but it deserves attention, that in all cases where ammonia combines with oxyacids, it carries with it an atom of water; that is, an atom of oxygen and an atom of hydrogen. Now ammonia, *plus* water, is symbolically represented as follows:—NH_3, HO; which is tantamount to NH_4O; that is, to 1 atom of nitrogen, 4 atoms of hydrogen, and 1 atom of oxygen. Now there are strong reasons for supposing that NH_4, that is, a compound of 1 atom of nitrogen with 4 of hydrogen, constitutes a METAL; this metal has been called *ammonium;* and to form the salts of ammonia, ammonium either combines directly with the *halogens*, that is, with chlorine, iodine, bromine, and their analogues; or else, as in the case of the sulphate, nitrate, &c., as oxide of ammonium; as appears in the following tables:—

CHLORIDE OF AMMONIUM, OR HYDROCHLORATE OF AMMONIA.

NH_4Cl, OR NH_3HCl.

	Equivalents.	Per cent.		Equivalents.	Per cent.
Ammonium .	18	33·3	Ammonia .	17	31·5
Chlorine .	36	66·7	Hydrochloric acid	37	68·5
	54	100·0		54	100·0

SULPHATE OF OXIDE OF AMMONIUM, OR HYDRATED SULPHATE OF AMMONIA.

NH_4O,SO_3; or, NH_3HO,SO_3.

	Equivalents.	Per cent.		Equivalents.	Per cent.
Oxide of ammonium	26	39·4	Ammonia .	17	25·8
Sulphuric acid	40	60·6	Water .	9	13·6
			Sulphuric acid	40	60·6
	66	100·0		66	100·0

The commercial *carbonate of ammonia* is not a very definite salt; as it usually occurs, it may be considered as including 2 atoms or equivalents of ammonia, 2 of water, and 3 of carbonic acid; it is therefore *a sesquicarbonate;* as follows:—

SESQUICARBONATE OF AMMONIA.

$2NH_3,2HO,3CO_2$.

	Equivalents.	Per cent.
2 ammonia .	34	28 8
2 water . .	18	15·3
3 carbonic acid	66	55·9
	118	100·0

I am thus particular in describing the composition of these ammoniacal salts, from their importance as *manures;* they are all powerful fertilisers, where the other requisite constituents of the crop, or what are usually termed its *inorganic* components, are present. They therefore form an essential part of guano; stable manure abounds in them; and so also with other similar composts. Salts

of ammonia are also a good deal used by calico-printers. In the operation of tinning and zincking sheet iron, where clean plates of iron are dipped into melted tin or zinc, the surfaces of the fused metals are covered with sal-ammoniac, which excludes air, and so prevents their oxidisement, which would fatally interfere with that perfect adhesion of the two metals which is sought for.

The average annual manufacture of ammoniacal salts is about 10,000 tons. For their production, the distillation of bone and of pit coal may be assumed as the chief sources of the ammonia.

I must now turn to a very different class of nitrogeniferous compounds, namely to those of which *cyanogen* is the base.

Cyanogen consists of 1 atom of nitrogen, in combination with 2 atoms of carbon; NC_2; or as follows:—

	Atoms.	Equivalents.	Per cent.
Nitrogen	1	14	53·9
Carbon	2	12	46·1
Cyanogen	1	26	100·0

Pure cyanogen is best obtained by heating *cyanide of mercury;* it is disengaged in the form of an inflammable gas, burning with a beautiful pink flame. When mixed with oxygen it explodes when set fire to, and affords carbonic acid and nitrogen as the results of its combustion. Cyanogen is a heavy gas, a little soluble in water, and of a peculiar penetrating smell, somewhat like that of bitter almonds: it is very poisonous.

Cyanogen, in combination with hydrogen, furnishes *hydrocyanic* or *prussic* acid, NC_2H; well known as intensely poisonous, even when in a very diluted state.

Pure hydrocyanic acid is best obtained by heating a mixture of cyanide of mercury and hydrochloric acid; it passes off in the form of a vapour, which by cold may be condensed into a very volatile liquid; and this, dissolved in water, constitutes the hydrocyanic or prussic acid of pharmacy.

Hydrocyanic acid is constituted as follows:—

	Atoms.	Equivalents.	Per cent.
Nitrogen . .	1	14	51·8
Carbon . . .	2	12	44·5
Hydrogen . .	1	1	3·7
Hydrocyanic acid	1	27	100·0

Neither cyanogen nor hydrocyanic acid are used in the arts, but their history is intimately connected with that of *Prussian blue*, which is a *cyanide of iron*, and which, in dyeing, calico-printing, and colour-making, is an article of considerable commercial importance; and its history is intimately connected with that of another cyanogen compound, manufactured also upon a large scale, and known to chemists as *ferrocyanide of potassium*, or more commonly, perhaps, as *prussiate of potash*, the production of which, as a preliminary step to the formation of Prussian blue, I will now endeavour to explain.

The manufacturer of this salt begins his operations by heating to redness, in an iron pot, any refuse animal matter containing nitrogen (such as chips of horn, hoof,

or skin, woollen rags, or the substance called *greaves*, (which is the refuse of tallow-melters, and consists chiefly of cellular membrane from which the fat has been expressed), along with common potash; the fused mass thus obtained, and which is called *prussiate cake*, is allowed to cool, and then lixiviated with water; this solution is evaporated, and yields a very impure salt, which is re-dissolved, and the second crystallisation allowed to go on very slowly, it being at least a fortnight before the contents of the coolers are disturbed; in this way, the beautiful pyramidal crystals of the prussiate are obtained. I may here remark, that the *iron* essential to the constitution of this salt, is sometimes derived entirely from the iron vessels in which the above-mentioned fusion is performed: but sometimes, also, iron-filings are added.

Ferrocyanide of potassium forms permanent lemon-coloured tabular and octohedral crystals, soluble in between 3 and 4 parts of cold water. When gently heated, the crystals lose their water of crystallisation, amounting to about 13 per cent., and crumble down into powder, which is the anhydrous or dry salt, and is composed as follows :—

ANHYDROUS FERROCYANIDE OF POTASSIUM.

	Atoms.	Equivalents.	Per cent.
Potassium . . .	2	80	43
Iron	1	28	15
Cyanogen . . .	3	78	42
Ferrocyanide of potassium	1	186	100

Prussian blue is a compound of cyanogen and iron, or a *cyanide of iron;* various views have, however, been taken respecting its composition, the discussion of which would be irrelevant here, so that I shall content myself with representing it as composed of about 45 per cent. of iron and 55 of cyanogen. It may be obtained as follows:—6 parts of protosulphate of iron (crystallised green vitriol) and 6 parts of ferrocyanide of potassium, are each separately dissolved in 15 parts of water; the two solutions are then mixed, and 1 part of sulphuric acid, and 24 of hydrochloric acid, are added, under constant stirring. After some hours, a clear solution of 1 part of chloride of lime and 80 parts of water is added, and the precipitate thoroughly washed and dried.

Prussian blue is of a peculiarly rich and intense colour, and when in lumps, its surface has a coppery tint; it is tasteless; inodorous; insoluble in water, alcohol, and dilute acids; and is not poisonous. The alkalies presently decompose it; thus, when digested in potash, ferrocyanide of potassium is formed, and oxide of iron is thrown down; so that as a dyeing material it does not resist the action of soap; and so also in regard to calico printing, the beautiful patterns which are obtained through its means, gradually yield to frequent washing, and leave the oxide of iron upon the cloth. Hence the great importance of *indigo* as a blue dyestuff, which resists the greater number of those agents by which Prussian blue is affected.

There are some other *cyanides* and *double cyanides,*

which are useful in the arts; thus, the double cyanides of gold and of silver are employed in electro-plating, and there are other purposes to which these compounds are applicable.

I must not pass over this part of my subject without mentioning the part which cyanogen plays in the production of *fulminating silver*, and more especially of *fulminating mercury*; this latter being in great demand as an ingredient in the charge of *percussion caps*, now so generally adopted in gun-locks. I will confine myself to the manufacture of *fulminating mercury*, premising, that *fulminating silver*, which is even more dangerous and violent, is made by a similar process, in which a nitric solution of silver is substituted for that of mercury.

Fulminating mercury was discovered in 1800, by the Hon. Edward Howard. To obtain it, a solution of mercury in nitric acid is mixed with alcohol, and gently warmed, when a violent effervescence ensues, accompanied by the decomposition of the acid and of the alcohol, and a grey powder is at the same time formed, which gradually deposits, and is then collected, washed with a little cold water, and very cautiously dried. This constitutes *fulminating mercury*. To make its composition intelligible, I must remind you that cyanogen is capable of combining with oxygen, and forming *three* very remarkable compounds, in which the relative proportions of the elements are identical, but the properties of each peculiar. These compounds have been

called *cyanic, fulminic,* and *cyanuric acids;* and when analysed, they each yield 76 *per cent.* of cyanogen and 24 *per cent.* of oxygen; so that as far as the *per centage* of carbon, nitrogen, and oxygen goes, no difference is discernible between them; yet they form very distinct compounds; and the cyanates, fulminates, and cyanurates, have each their characteristic peculiarities. The cause of these apparent anomalies seems to lie in the *atomic constitution* of the respective salts; and they furnish a good instance of what chemists have termed *isomerism.* In the *cyanates,* 1 atom of cyanic acid is combined with 1 atom of base; in the *fulminates,* 2 atoms of acid are combined with 2 of base; and the *cyanurates* are constituted of 3 atoms of acid and 3 of base; so that the following will be the symbolic representations of these several acids :—

Cyanic acid = NC_2O, or Cy O.
Fulminic acid = $N_2C_4O_2$, or Cy_2O_2.
Cyanuric acid = $N_3C_6O_3$, or Cy_3O_3.

I have nothing further to say here respecting cyanic and cyanuric acid; but as regards the *fulminic acid,* I may remind you that the greater number of its compounds are explosive, and that it may be transferred from one base to another. Fulminate of mercury is composed of

	Atoms.	Equivalents.	Per cent.
Suboxide of mercury	2	416	86·0
Cyanogen . .	2	52	10·7
Oxygen . . .	2	16	3·3
Fulminate of mercury	1	484	100·0

When fulminating mercury is heated to between 300° and 400°, it explodes with a bright flame and much violence; and if substituted for gunpowder, its combustion is so rapid and sudden that, like other detonators of the same class, it bursts the gun without expelling the ball. But it also explodes by percussion and friction, and a little heap of it placed upon an anvil and sharply struck by a hammer, goes off with a deafening noise. Many hundredweights of this dangerous article are annually manufactured; it requires great care both in its production and transport.

And now that we are upon the subject of *explosive compounds containing nitrogen*, I may as well introduce two others, which in point of dangerous and facile explosiveness exceed all other known bodies, and consequently require to be made and handled with the utmost circumspection. The compounds to which I allude are those of nitrogen with chlorine, and nitrogen with iodine; *the chloride*, and *the iodide of nitrogen*. They resemble each other in their atomic constitution, being respectively composed of 1 atom of nitrogen and 3 of chlorine, and 1 atom of nitrogen and 3 of iodine; and they are each obtained through the medium of *ammonia*, which you will recollect consists of 1 atom of nitrogen, and 3 of hydrogen.

To obtain *chloride of nitrogen*, NCl_3, we proceed as follows: we fill a tall, and very clean glass jar, with chlorine, and invert it in a perfectly clean glass or porcelain basin, filled with a solution of sal-ammoniac;

this solution gradually absorbs the gas, and slowly rises into the jar, acquiring a yellow colour, and becoming covered with a yellow film; at length small globules, looking like a yellow oil, collect upon the surface of the solution, and successively fall into the basin beneath. These globules are the compound in question, and a good deal of tact is required in removing them. The best thing for the purpose is a very small and clean glass syringe, by which they may be sucked up, and so transferred into small basins of water, at the bottom of which they lie looking like a heavy harmless oil, and remaining quiet enough, and gradually decomposing and disappearing, if let alone; but if touched by a drop of oil, or an atom of grease, or a morsel of phosphorus, exploding with such violence as to shatter the basin, and scatter the water. You will now understand why the most rigid cleanliness is required in regard to the vessels in which this body is made and retained. With a jar of chlorine holding about three pints, we may obtain about half a teaspoonful of the chloride, and this should be removed and divided, by the help of the syringe, into separate portions, each about the size of a mustard seed, or at most of half a pea. Such a portion may be touched under water with a morsel of phosphorus, or a little grease, at the end of a long stick, when we desire to witness the explosion; but it would be imprudent to meddle with larger quantities; and even in dealing with these, too many precautions cannot be resorted to, for Dulong, its discoverer, lost an eye and a finger, and

Sir H. Davy was severely wounded in the face, by the effects of its detonation. It is said that it sometimes explodes spontaneously, or by very slight friction, but I never knew this happen, though I have prepared it, I suppose, a hundred times.

But dangerously unstable as is this chloride of nitrogen, the corresponding *iodide of nitrogen* is yet more so. It, also, is easily prepared: to this end, put a little iodine into a wine glass, and fill it up with a pretty strong solution of ammonia; the iodine presently begins to decompose the ammonia; hydriodic acid is one of the results, and the other a *black powder*, which is the compound we are in search of; it is formed by the union of the nascent nitrogen of the decomposed ammonia, with a portion of the free iodine present. We must now pour off the liquid, and with a little spoon, carefully place the wet powder, in small separate heaps, upon blotting paper, where it must be allowed to dry spontaneously in the open air. When dry it can no longer be meddled with; it detonates upon the slightest touch; and when one of the little heaps explodes, the neighbouring ones generally follow its example. You observe that, when it detonates, the purple fumes of iodine are perceptible, and it exhales an acrid odour, something similar to that of the chloride. The energetic rapidity of this explosion is well illustrated by the violence with which the paper upon which it rested is rent asunder, and yet, a card placed over the exploding heap, is not blown away.

And now, in looking back upon the subject, you will, I think, allow that nitrogen is a very extraordinary and interesting element. Its quiescent imbecility in its gaseous and isolated state is curiously contrasted with the mischievous activity of very many of its combinations; and the phenomena of the metallisation of ammonia tempt us to hope and believe, that some of these days we may know something more of the constitution of the metals, while, even now, it justifies us in hypothetically regarding hydrogen as a gaseous *metallic body*, and water as a *metallic oxide*.

In taking leave of the compounds containing nitrogen, which have formed the subject of this day's lecture, and more especially in reference to the ammoniacal and cyanic compounds, it is curious, and not uninstructive, to reflect upon the sources whence they are derived, the transmutations in which they are concerned, and the purposes to which they are directly or indirectly subservient. Look, for instance, at a horse, an ox, an ass, or any such animal: whilst *living* it *consumes*, as we say, the grass of the field,—that is to say, it so concentrates and condenses certain of the proximate principles of the vegetable kingdom, so assimilates or digests them, as in the first instance to form its *blood*; and then, to elaborate the proximate elements of that blood into new products, some of which are concerned in the *growth* of the animal, that is, in forming skin and bone, brain and nerve, muscle and membrane, and so on. Others undergo that slow kind of combustion which maintains

animal temperature, and gives rise to the *products* of *respiration*, the principal of which is carbonic acid; and which, passing into the air, are absorbed and decomposed by living plants, and in their organism are partly retained and consolidated, and partly returned into the atmosphere to restore and purify it; the animal rejecting what the vegetable requires, and the vegetable rejecting what the animal requires.

When *dead*, the animal, if left to itself, undergoes the various phases of putrefaction, and is more or less gradually and entirely resolved into principles eminently conducive to vegetable nutrition. But, with the exception perhaps of the majority of the human race, such a consummation is rarely permitted; on the contrary, the carcase becomes the fountain of a new series of useful applications and ingenious manufactures. First, the hair is shaved off for the service of feltmakers and plasterers; the hides and skins pass into the hands of the tanner and leather-dresser, and are made into boots and shoes, harness and saddlery, gloves, bookbindings, and the many other articles which those trades supply; whilst the smaller clippings are boiled into glue or size, for the service of the carpenter, paper-stainer, and whitewasher, or are submitted to those more refined operations which I have elsewhere brought before you, and are so purified and metamorphosed, as to represent preferable substitutes for isinglass; and, in the forms of jelly and blancmange, to administer to the luxuries of the table: or maybe they are boiled down into portable

soup, and the residue, under the familiar name of cats'-meat and dogs'-meat, becomes the food of our domestic carnivora. By the operation of *boiling*, to which the flesh, bones, and general offal is commonly subjected, the *fat* is separated, and is the source of the soap with which we cleanse our persons and linen, and of the candles which illuminate the palace as well as the cottage. Bone itself is applied in a thousand ways, in turnery, and in the mechanical arts; and when rasped, is a culinary source of gelatine, as in hartshorn shavings, for instance. Ground bone is an invaluable manure, not merely as a source of nitrogen, but as giving phosphate of lime to the soil, which, absorbed into the plant, forms an element of the crops, and regenerates bone in a new race of animals. When bone is subjected to destructive distillation, we have already seen the abundance of ammoniacal products which it affords, amongst which are sal-volatile and smelling salts; and the residuary bone-black and animal charcoal are not only useful as pigments, of which large quantities are demanded for the manufacture of blacking, but also on account of the peculiar bleaching or decolouring powers belonging to this variety of charcoal, and which render it an essential agent in conferring the snowy whiteness upon double-refined sugar. Bone, too, is the great source of phosphorus, and consequently of lucifer-matches, of which millions are daily manufactured and consumed. Lastly, the nitrogeniferous principles of the carcase we have been contemplating, are the source of *cyanogen* and its

compounds. *Prussiate of potash* owes its origin to horn and hoof, and to bone and skin: thence the remedial powers of prussic acid, and thence *Prussian blue*, which carries us into the precincts of the dyer and calico-printer, of the paper-hanger and decorator. Such is a scanty outline of the final destinies of the dead animal. When we contemplate these matters, we are reminded of Hamlet's query,—"Why may not imagination trace the noble dust of Alexander, till he find it stopping a bunghole?" and of the plausible reasoning by which he supports the philosophy of his argument.

LECTURE X.

ON THE PHENOMENA AND PRODUCTS OF FERMENTATION.

THE term *fermentation* is commonly employed to signify the spontaneous changes which certain vegetable solutions undergo, and which terminate in the production of an intoxicating or *fermented* liquor. We also sometimes speak of *panary fermentation*, or that sustained by a mass of dough during its conversion into bread; of *acetous fermentation*, or that concerned in the production of vinegar; and of *putrefactive fermentation*, or, in common language, *putrefaction*. These several results of fermentation are commonly known and well understood; but of late years the meaning of the term *fermentation* has been greatly extended, and has been applied to many other changes sustained by organic matters. Dumas, for instance, and he is deservedly looked upon as high chemical authority, enumerates no less than twelve species of fermentation. But I shall not complicate my subject by bringing all these before you; and shall rest content, in reference to the avowed object of these lectures, with an endeavour to give you such an account of vinous and of acetous fermentation as can be condensed into the limits of a single lecture, for to-day I must take my leave of you.

SUGAR is the principal subject concerned in *vinous fermentation*, and no vegetable juice can be made to undergo the process which does not either originally contain it, or some other principle, such for instance as *starch*, which is capable of conversion into sugar. For what relates to these conversions, I must refer you back to the lecture on sugar; and will now merely remind you, that the only kind of sugar susceptible of fermentation, is *glucose*, or *grape sugar*; so that, whatever sugar, or source of sugar, we start with, it must, in some way or other, be changed into *glucose* before it can become susceptible of the curious transmutations which we are about to discuss. A hasty glance at the production of *beer* and of *wine* will not only form a useful, but a necessary prelude to our subject; meaning, by the former, the beverage derived from *malt*; and by the latter, that obtained from the juice of the *grape*.

In this country *beer* is almost exclusively made from barley which has undergone the process of *malting*; that is, has been allowed to germinate up to a certain point, after which the further growth of the seed is stopped by drying it at a temperature of about 150°. The change thus effected in the grain consists chiefly in the conversion of a portion of its starch into gum and sugar; the original barley containing about 90 per cent. of starch, and 9 of gum and sugar; whereas the malt contains about 70 only of starch, and nearly 30 of gum and sugar. But, besides this, malting gives rise to the formation of another substance, which is

called *diastase*, and which may be separated from it in the form of a white powder, possessed of a remarkable power of converting starch into gum and sugar; to such an extent, indeed, that one part of it is capable of thus modifying 2,000 parts of starch. Here, then, you will not fail to remark, that the influence of *diastase* in the conversion of starch into sugar, much resembles that of the diluted sulphuric acid, the action of which I showed you in the lecture on sugar; the mere *presence* of the diastase, and of the acid, are sufficient; they appear to suffer no change or decomposition; so that their action is what we have elsewhere called *catalytic;* that is, we know the effect, but are ignorant of the cause. It is curious to observe the rapidity of this action of the malt, or rather of its diastase; here I have about a quart of a thick viscid solution of starch; I add to it about a table-spoonful of a strong infusion of malt, and maintain the mixture at a temperature of about 160°. In a few minutes we observe a complete liquefaction, in consequence of the first step of the change, namely, that in which the starch passes into that modification of gummy matter which has been called *dextrine;* but, as yet, there is no sweetness; this, however, gradually succeeds; and in the course of four or five hours, abundance of sugar will have been formed. When, in this experiment, we set out with a determinate weight of starch, we find that the sugar produced somewhat exceeds it; and by referring to our table of the ultimate composition of starch and glucose, you will see

that the latter includes a larger proportion of the elements of water than the former; so that, by the *fixation*, if we may so say, of a portion of water, starch becomes glucose. Dextrine and starch have the same composition, so that they may be said to be *allotropic bodies*.

You will now understand the necessity of paying great attention to the temperature at which malt is dried; when this is between 140° and 160°, it is called *pale malt*, and is in the best condition for the production of beer; at higher temperatures the diastase is more or less modified, and its power of changing starch into saccharine matter proportionately affected, or even destroyed. *Yellow* or *amber* malt is dried at about 212°; *brown* or *blown* malt, at about 300°, and in this the diastase is destroyed, but it is used to give tint and taste to the beer; *roasted* or *black* malt, which has in fact been parched, is chiefly used to give that deep colour which characterises porter.

Good pale malt is plump, and when crushed, appears full of white pulverulent starch: it has a pleasant odour and sweetish taste; and when chewed, forms a pasty mass; it floats upon water, whereas unmalted barley sinks; and when finely ground and rubbed up with water at the temperature of 160°, it almost entirely dissolves, leaving little else than its husk behind.

This infusion or solution of malt is technically known under the name of *wort*; and in the brewery, the process by which it is obtained is called *mashing*, and

the vessel used for the purpose, the *mash-tun*. During the mashing, the unchanged starch of the malt is progressively saccharised, so that the wort gradually becomes more and more sweet under the operation. Much practical skill is required in conducting this process; and the *temperature* at which the several mashings are conducted, so as to exhaust the malt, must be strictly attended to. The insoluble residue, known under the name of brewers' grains, consists of little else than husk or ligneous fibre, with traces of coagulated albumen, and other foreign matters; it is used by the London cowkeepers as food for their cattle.

The quantity of wort obtainable from a given quantity of malt will depend upon the kind of beer we require, its strength being determined by its specific gravity, which is ascertained by a hydrometer, or, as it is here generally called, a *saccharometer;* taking the extremes as strong ale and table beer, the specific gravity of the wort will vary between 1·100 and 1·020; these numbers having reference to water = as 1·000.

The wort is next boiled with *hops,* which were first introduced into this country from Flanders, in the reign of Henry VIII. Their active constituents are essential oil, bitter extractive, and a little gum and resin. A very important part of the management of hops consists in the manner of drying them, which is performed in a kind of kiln, called, in Kent and Sussex, *oast houses;* they are, for the most part, very unscientifically constructed; and would apparently admit of easy and im-

portant improvements. To give them a proper marketable colour, and to prevent the communication of a disagreeable tint to the beer, the hops are subjected to a species of bleaching, or fumigation with sulphurous acid, and are finally packed in *bags*, or *pockets*, and subjected to considerable pressure, so as to exclude the access of air.

The relative proportion of hops used in beer varies according to the desired quality of the liquor; about one-twentieth of the weight of the malt is, I believe, the average proportion. Their influence is very important; they diminish the tendency of the liquor to secondary fermentation, and other mischievous changes; by their aromatic bitter they cover sweetness, and impart a new flavour and fragrancy. These qualities are partly referable to the volatile oil of the hop, a part of which is dissipated in the steam escaping from the boiling-coppers, which should be so constructed as to retain the largest possible quantity of *aroma*.

No substitute can be found for the hop as regards the agreeable qualities which it imparts to the finished beer, except, indeed, as respects mere *bitterness;* and the present rage for *bitter small beer* has led to the use of quassia, camomile, gentian, and some other pharmaceutical bitters, which, when judiciously and homœopathically employed, are fit enough for the purpose, being harmless and inexpensive; but they are all open to the palpable objection of leaving more or less of a permanent, and not pleasing bitterness, on the palate,

totally different from that resulting from the hop. The *nux vomica*, which contains the highly poisonous, and at the same time intensely bitter alkaloid *strychnia*, is said to have been imported in such large and increasing quantities into this country, as has led to the suspicion of its employment for these purposes; so that some brewers have deemed it necessary to refute such notions by a reference to the analytical labours and testimonials of the highest chemical authorities. These, and many other notions, regarding the similar applications of cocculus indicus, opium, tobacco, and other narcotic poisons, have their origin in the discoveries and exposures which the officers of the excise have occasionally divulged, and are, to a certain extent, sanctioned by the disclosures of *treatises on brewing*, by "*old practitioners*," and by the existence of *brewers' druggists*; and, no doubt, obscure and illegal brewers do resort to such and other adulterations; but it seems probable that the retail dealers are the greatest sinners, and that public-houses and beer-shops are the chief seats of sophistication. It is curious to observe the miscellaneous products of the row of pumps which adorn the *taps* of these establishments.

You may consult Mr. Accam's book on "Culinary Poisons," if you desire further details upon these matters, and we will now resume the legitimate operations of the brewery.

The contents of the brewing-copper, that is, the decoction of hops in wort, is run off through a coarse

strainer, and *cooled* as rapidly as possible down to 60°, or lower. This operation, which is a very important one in respect to the final result, is generally conducted in very shallow vessels, placed in some very airy situation, and subject to currents of air, often aided by fanning machinery. Sometimes the hopped wort is transferred through an extensive series of tubes, upon the exterior of which a current of cold water is made to run in a contrary direction; the object of these and other *coolers* and *refrigerators*, being to effect their purpose quickly and completely.

When duly cooled, the liquor is let into the *fermenting vessels*, or *gyle-tuns*, which must be large enough to contain the worts, and leave eight or ten inches of the depth unoccupied; they also usually have a framework of loose boarding on the top, to receive the rising head of froth. A sufficiency of *yeast* having been added, fermentation comes on in six or eight hours, and a series of phenomena ensues to which I must call your special attention in reference to the theory of the changes. A scum or foam gradually collects upon the surface of the liquor; its temperature rises; and *carbonic acid* escapes in gradually increasing quantity; at length the evolution of gas ceases, the liquor becomes quiet and clear, and is now less sweet, of diminished density, and has become *intoxicating*, in consequence of the generation of *alcohol*; in fact, a large proportion of the saccharine contents of the wort has disappeared by conversion into alcohol and carbonic acid; the former

is retained, while the larger portion of the latter has escaped in its gaseous state.

When the object of brewing is not the production of beer, but of ardent spirits, the wort, or *wash*, as it is here called, is not obtained from malt only, but from raw grain, mixed with a small quantity only of malted grain, the diastase of which is sufficient, as already stated, to convert a large proportion of starch into fermentable sugar. But these, and other modifications of the fermentative process, I must not further dwell upon, inasmuch as they are independent of the chemistry of the operation.

And now a word or two upon the subject of *wine*, before we enter upon our theoretical details.

Wines, properly so called, are derived from the juice of the grape, which, when expressed from the ripe fruit, is termed *must;* it holds many substances in solution, the principal of which are *glucose* or *grape sugar*, starch and gum, albumen and gluten, tannin and colouring matter, bitartrate of potash, or, as it is usually called, tartar, a little malic and citric acid, a little tartrate of lime, and some other saline matters which I need not specially enumerate. But we also find in must traces of an oily matter, derived either from the seeds or husks of the grape, or contained in the juice itself, and which, though very small in quantity, has an important influence on the odour and flavour, or *bouquet*, as it is termed, of the *wine*.

The grape sugar, or glucose, is the source of the *alcohol* of the wine; and the phenomena of its transmu-

tation into alcohol and carbonic acid, or in other words, its *fermentation*, is precisely the same as in the case of beer; the *strength* of the wine being dependent upon the proportion of sugar originally contained in the must, or at least of that portion of it which has been allowed to undergo decomposition; for in *sweet wines* a large proportion of unchanged sugar is allowed to remain; whereas in *dry wines*, nearly the whole has been used up. The proportion of sugar in the original must may be judged of by its density; the greater the specific gravity of the grape juice, the greater its fermentable contents. In bad and wet seasons, saccharine matter is often so far deficient, as to require the addition of glucose to the must; or if not of glucose, of cane sugar, which is transmuted during fermentation. In these cases it was formerly supposed that the deficiency of sugar in grapes, might, as far as relates to the *strength* of the wine, be compensated for by the subsequent addition of brandy; but this is a mistake; and a much more satisfactory result is obtained by adding such a quantity of sugar to the must as is required to bring it up to the standard of favourable seasons; and in those cases, starch sugar should be preferred to cane sugar; and sugar obtained from the grape itself is preferable to either. You will observe that in wine making no yeast or other ferment is added, for there is a natural ferment contained in the must, which enters at once into vinous fermentation when the temperature is sufficiently high, namely, about 70°. This pre-existing

ferment is an albumino-glutinous substance; in other words, considering it merely in reference to its chemical composition, it is a *nitrogeniferous* principle; and this being the case, you will naturally ask why it is that the juice of the grape does not ferment in the grape itself; how it is that ripe grapes, even when cut from the vine, not only exhibit no such tendency, but, as long as the skin is entire, shrivel up into *raisins*. This anomaly was hypothetically solved by assuming that the gluten or ferment was shut up in distinct vesicles, which, on mashing or pressing the fruit, were ruptured, and so became active. But Gay Lussac found that when thoroughly bruised grapes were carefully excluded from air; or rather, when the grapes were crushed and pressed out of the presence of *oxygen*, no change ensued; but that even a momentary exposure of the pulp to air, or oxygen, was sufficient to endue it with the power of fermentation. We may therefore, I think, venture to conclude, that the action of oxygen on certain nitrogeniferous principles existing in the grape juice, confers upon them the properties of yeast. It is curious how admirably the exclusion of air is provided for by the natural texture of the grape, which does not allow its ingress, and yet admits of the egress or transpiration of aqueous vapour, as shown by the spontaneous desiccation of the berry.

If we now compare the constituents of wine with those of the grape juice which has afforded it, it will appear that a great part of the sugar is replaced by alcohol, and that certain substances which were held in

solution in the original juice, are now no longer soluble in the vinous liquor. *Water, alcohol, sugar, colouring matter,* and *tartar* are the leading components of wine; so that, in consequence of the presence of *tartar,* all wines have more or less *acid* reaction upon blue litmus paper. Many wines contain *tannic acid;* champagne, and other sparkling wines, abound in *carbonic acid:* but there is also in all wines, more or less of an *odorous principle,* partly pre-existing in the grape, but often formed during fermentation; it has some of the characters of an essential oil; it is sometimes very evanescent, and small in quantity; sometimes more persistent and abundant. The odorous matter generated by fermentation is now considered as a species of *ether;* it has been called *œnanthic ether;* a combination of oxide of ethyle (C_4H_5O), with œnanthic acid ($C_{14}H_{13}O_2$). These odorous compounds, constituting the *aroma* or *bouquet* of wines, appear to have their origin in certain fatty acids of the grape, which are converted by oxidisement into more powerful acids, and consequently more disposed to form ethers; and more volatile, and therefore calculated to affect the odour and flavour of the wine.

The *colouring matters* of wine are derived, with very few exceptions, from the *husk of the grape;* they acquire solubility in proportion as alcohol is evolved during fermentation; and if originally blue, are reddened by the acids of the pulp. The seeds, and often the husks of grapes, also contain tannine, which communicates a degree of astringency to the wine, and the property of

darkening the salts of iron. Sometimes *extraneous* colouring matters are added; as where white wines are changed to red, or pale sherry into brown.

The change which wines undergo in *cask*, is sometimes connected with a continuance of the fermentation, during which, it deposits tartar, and tartrate of lime, in combination with extractive and colouring matter. The quantity of tartar held in wine is inversely as its strength; for tartar is nearly absolutely insoluble in strong wines, which therefore are always less acid than weaker ones. But this holds good only of wines made from grapes, the acid flavour of which almost exclusively results from the presence of bitartrate of potash. Other fruits and juices from which liquors called *wine* are sometimes prepared, owe their acidity to free tartaric, malic, or citric acids, which are as soluble in dilute alcohol as in the original juices, and are not therefore thrown down, as is the case with tartar, by the generated alcohol; such wines accordingly may be very strong, but at the same time very acid. The peculiar fitness and excellence of the *grape*, as a source of wine, may in great measure be ascribed to the cause I have just explained.

In *bottles* the same changes continue as in the cask, but they are very slow and imperfect; the wine deposits its crust of extractive and tartar; and in some wines which have been very long kept, crystals of tartrate of lime are not uncommon: the perfume or *bouquet* of the wine is also much influenced by its age in bottle.

There is no apparent limit to the time for which some wines may be kept in bottle, not only in a perfect, but apparently improving state, such as *sherry* and *madeira*. Some red wines, and more especially *port*, improve for a time, partly in consequence of the deposition of extractive, tannine, and tartar; and then they deteriorate, losing colour and flavour. The bouquet of *claret* improves up to a certain point, and is then apt to decline; yet the deposit from that wine, and the apparent change which it suffers in bottle, is remarkably small. I have seen it, after twenty-five years, to have deposited nothing more than a very thin transparent film of colouring extractive, nearly equal over the whole interior of the bottle. Many years ago I had an opportunity of examining some bottles of wine which were found in a cellar beneath the foundations of a house near the Bank, which was pulled down to make room for the new buildings in Princes-street. There was evidence of their having lain there since the fire of London in 1666. The bottles themselves are of an antique form; and the glass decomposing exteriorly; and in places, corroded and iridescent. The wine contained in them was of two kinds; one appeared to have been Malaga, or some similar strong wine, and was really in a very fair condition; the other was supposed to have been claret, and resembled muddy water. The corks had so far perished as to have become pulpy, and the wine was retained by the coat of rosin into which they had been dipped.

Wines are liable to certain *diseases*, as they have been called, some of which are curable. It sometimes, for instance, happens, that a secondary fermentation is set up in the wine in cask, which, if allowed to continue, would destroy the whole of the saccharine contents of the wine, and leave it with a bitter flavour. This may be checked by sulphurous acid; in other words, by transferring the wine into a cask in which sulphur has been burned. Sometimes *viscous fermentation* ensues, as in ropy champagne: this is said to be curable by the skilful administration of a little pure tannine. Sometimes a slight musty flavour pervades a pipe of wine, which may be removed by agitating it with a small proportion of very pure and tasteless olive oil: the oil acquires the musty flavour, and may be withdrawn from the surface; but this evil, which is sometimes called *tasting of the cask*, and corkiness, is very difficult of cure, especially where it is referable to the grapes.

The quantity of *alcohol* contained in different wines, and in different samples of the same wine, is very variable, and depends upon many accidental causes affecting the quantity of saccharine matter originally existing in the liquor before fermentation. So also in respect to beer, the variation in alcoholic strength is affected by the original contents of the wort, and by the extent and method of fermentation. In respect to brandy, and other products of distillation, the quantity of alcohol which they contain is easily regulated, and such liquors are usually of a more uniform composition or strength.

To determine the *quantity of alcohol* in any of these liquors, we generally neutralise any acid that may be present, by a little lime, and then, carefully distill a given measure, until from one-half to three-fourths has passed over; using a proper and effectual condensing apparatus for the purpose, so that no vapour may be lost. A quantity of distilled water is then added to the portion which has distilled over; so as to make up the *original volume* of the liquor under trial: this mixture is well shaken, and set aside for a day or two in a stopped bottle: its *specific gravity* is then accurately ascertained; and from this datum the quantity of alcohol *per cent.* by measure is determined by reference to the tables drawn up for the purpose. There is of course no direct relation between the original density of the wine or beer submitted to examination and its alcoholic strength, inasmuch as its density is affected by all the matters which the liquors hold in solution.

I now present you with a *table* giving the quantity of alcohol *per cent.* by measure, contained in a variety of wines: it is abridged from a much more extensive table which I have elsewhere published. I have added to it several kinds of beer, and of some other spirituous liquors, to enable you to compare their relative alcoholic strengths. But I must remind you, whilst upon this subject, that the quantity of alcohol obtainable from the different liquors included in this catalogue, must not be too rigidly assumed as accurately indicating their intoxicating powers, or their other mischievous

influences upon the system; for alcohol, or brandy, whisky, and so forth, diluted by water till of the same absolute alcoholic strength as wine, will generally be more hurtful; for there can be little doubt that the peculiar condition in which the alcohol is left in wine, beer, or other fermented liquors, differs from that attainable after the alcohol has been separated by the process of distillation. For instance: in round numbers, the alcoholic strength of ordinary port wine does not fall much short of that of a mixture of equal parts of brandy, or of whisky, and water; yet, equal quantities of the said port, and of the diluted spirits, would in most persons produce different effects. The acid and other matters, existing in the wine, may also modify and mollify the influence of the alcohol; and the essential oils contained in brandy, gin, whisky, and more especially in rum, no doubt add fuel to their fire. Hence, the dram drinker is generally worse off than the wine bibber.

The *alcohol* of the following table is not *absolute alcohol*, but that usually called *rectified spirit of wine*; it includes about 10 per cent. of water.

TABLE OF THE QUANTITY OF ALCOHOL, PER CENT. BY MEASURE, CONTAINED IN WINES, BEERS, AND DISTILLED SPIRITUOUS LIQUORS.

WINES.

PORTUGUESE.

	Maximum.	Minimum.	Average.
Port . .	25·88	19·00	22·40
White Port . .	15·97	13·90	14·94

	Maximum.	Minimum.	Average.
Colares	21·84	17·60	19·75
Carcavella	19·20	18·10	18·65
Lisbon	16·14	18·94	17·54
Bucellas	17·20	19·79	18·49
Vidonia	20·24	18·25	19·25
SPANISH.			
Sherry	23·98	13·86	18·92
Amontillado	18·40	12·63	15·51
Tent	13·90	13·30	13·60
Alba Flora	17·26	17·26	17·26
Malaga	18·94	17·26	18·10
MADEIRA, ETC.			
Madeira	24·42	19·24	22·27
Sercial	21·40	15·41	18·42
Red Madeira	22·30	18·40	20·51
Malmsey	16·40	12·86	14·63
Teneriffe	19·79	19·79	19·79
FRENCH.			
Claret (stronger)	17·11	12·91	15·10
Claret (weaker)	9·00	7·70	8·38
Champagne	13·80	11·30	12·61
Burgundy	16·60	11·95	14·27
Hermitage	17.43	12·32	14·87
Cote Roti	12·32	12·32	12·32
Rousillon	19·06	17·26	18·13
Sauterne	14·22	11·00	12·61
Nice	14·63	14·63	14·63
Barsac	13·86	12·80	13·33
Vin de Grave	13·94	12·80	13·37
Grenache	21·24	21·24	21·24
Frontignan	12·79	11·00	11·89
Rivesalt	9·31	10·56	9·93
Lunel	18·01	10·52	14·26

	Maximum.	Minimum.	Average.
SICILIAN AND ITALIAN.			
Marsala . . .	26·03	18·20	22·12
Lissa	26·47	15·90	21·18
Lachryma . . .	19·70	20·22	19·96
Syracusa . . .	20·00	15·28	17·60
Etna	19·00	18·16	18·58
Falernian . . .	18·99	20·00	19·50
Aleatico . . .	17·00	16·20	16 60
Carrara . . .	16·06	16·54	16·30
GERMAN.			
Hochheimer . .	14·37	8 88	12·08
Johannisberger . .	8·75	8·00	8·35
Rudesheimer . .	12·22	6·90	9·56
Oestricher . .	10·66	8·46	9·56
Zornheimer . .	10·11	8·75	9·43
Bodenheimer . .	13·96	13·96	13·96
Rhenish (?) . .	7·58	7·00	7·29
CAPE.			
Cape Madeira . .	22·94	18·11	20·51
Constantia . .	19·75	14·50	17·12
HUNGARIAN.			
Tokay . . .	9·88	9·88	9·88
PERSIAN.			
Sheraaz . . .	19·90	12·85	16·37
BRITISH.			
Grape wine . .	18·11	12·60	14·85
Raisin wine . .	26·40	23·20	25·12
Currant wine . .	20·55	10·50	15·52
Gooseberry wine .	11·84	9·90	10·37
Orange wine . .	12·26	10·26	11·21
Elder wine . .	8·80	8·00	8·40
Mead	7·32	7·32	7·32

	Maximum.	Minimum.	Average.
Cider . . .	9·87	5·21	7·54
Perry . . .	9·90	6·10	8·00
MALT LIQUORS.			
Ale, Burton . .	8·88	6·22	7·55
Do. Edinburgh . .	7·86	5·75	6·80
Do. London . .	8·90	5·00	6·95
Do. Dorchester .	5·56	5·00	5·28
Do. Home-brewed .	10·84	9·85	10·34
Brown Stout . .	6·80	3·80	5·30
London Porter . . .	5·00	3·00	4·00
London Small Beer .	2·30	0·90	1·60
Bitter Beer . .	2·90	2·54	2·72
SPIRITUOUS LIQUORS.			
Brandy . . .	53·40	48·00	50·00
Rum	53·68	46·60	50·14
Gin	57·60	39·90	48·75
Scotch Whisky . .	54·32	53·65	53·98
Irish Whisky . .	53·90	53·00	53·45

I must now shortly discuss the *theory* of fermentation. I have already said, that if we set out with cane sugar, it becomes, in the first instance, converted into glucose or grape sugar, and that this, during fermentation, is resolved into carbonic acid and alcohol; that to produce these changes, some substance besides sugar and water is requisite, namely, some *ferment;* that a certain temperature is required, say between 70° and 80°; and that the presence of air is not only unnecessary, but generally injurious. Now you will recollect, by referring to what I said in the lecture on sugar, that an

atom of *dry grape sugar* may be represented as including 12 atoms of carbon, 12 of hydrogen, and 12 of oxygen: an atom of *alcohol* contains 4 atoms of carbon, 6 of hydrogen, and 2 of oxygen: and an atom of *carbonic acid* is constituted of 1 atom of carbon, and 2 of oxygen; they may therefore be thus symbolically represented:—

1 atom grape sugar . .	$C_{12}H_{12}O_{12}$
1 atom alcohol . . .	$C_4H_6O_2$
1 atom carbonic acid . .	CO_2

Or, if we look at the final results of perfect fermentation, one atom of grape sugar affords 4 atoms of carbonic acid and 2 atoms of alcohol:—

1 atom of dry grape sugar = $C_{12}H_{12}O_{12}$	4 atoms of carbonic acid ·	C_4 O_8
	2 atoms of alcohol .	$C_8H_{12}O_4$
		$C_{12}H_{12}O_{12}$

So that 180 parts of *dry grape sugar*, would yield 88 parts of carbonic acid, and 92 of alcohol.

If we set out with common, that is *crystallised* cane sugar, = $C_{12}H_{11}O_{11}$, it yields somewhat *more than its weight* of carbonic acid and alcohol; inasmuch as, in the first instance, it assimilates to itself an additional atom of *water*, = HO, to become grape sugar. If, on the other hand, we commence with commercial, or common crystallised grape sugar, = $C_{12}H_{14}O_{14}$, it yields *less than its weight* of carbonic acid and alcohol; because it contains 2 atoms of water, = H_2O_2, in excess: hence we have, on the one hand, 171 parts of *cane sugar* producing

180 parts of carbonic acid and alcohol; and, on the other, 198 parts of common grape sugar producing the same result.

In the production of beer and wine, and in the fermentation of a solution of sugar in water, the results, as far as the mere production of alcohol is concerned, are the same; that is, the sugar is decomposed *in consequence of the presence of a ferment.* If you carry on the process, as you have just seen it, in a glass vessel, and closely observe what goes on, you will remark that the particles of the ferment (*yeast,* in this instance) become covered with bubbles of carbonic acid, which cause them to rise to the surface of the liquor, where they discharge it, and, as they again sink, they gradually acquire a fresh coating of bubbles, which they carry up as before; and thus that *motion* of the whole mass of liquor, so characteristic of fermentation, is produced. When the process is complete, the liquor clears, the yeast falls to the bottom, the sugar has vanished, and is, as it were, replaced by alcohol.

Now as these extraordinary changes only occur where *yeast, or some equivalent ferment,* is present, its *modus operandi* has, of course, excited much curiosity.

It appears that the actual contact of the particles of the yeast with the dissolved sugar, is essential; for yeast which has been deprived of all matters soluble in water, is still effective. It further appears, that the efficient part of the yeast is composed of cells containing minute globules, which globules actually *germinate* in the saccharine

liquor, and produce a microscopic fungus, which seems to grow at the expense of the sugar, giving out carbonic acid and leaving alcohol. According to Mitscherlich, the *ultimate composition* of the germinating globules is as follows: namely, 47·0 of carbon, 6·6 of hydrogen, 35·8 of oxygen, and 10·0 of nitrogen; together with traces of sulphur, phosphorus, and certain fixed bases. Of these particles, or globules, from two to three parts are required for the decomposition of 100 parts of sugar; and if there be excess of sugar, it remains unchanged; if, on the contrary, there be excess of yeast, it forms a deposit, part of which is cellular and active, and part composed of ruptured and inefficient cells: it is assumed then, that during fermentation, a certain portion of the yeast plant, or fungus, dies, and is decomposed; whereas the active globules retain their vitality. It further appears, that the defunct globules have lost the greater part, if not the whole of their nitrogen; and certainly it does appear, that one of the results of the changes which ensue during saccharine fermentation is the formation of *ammonia*, which, although in very small quantity, may always be found when skilfully searched for.

Various mixtures *of pure alcohol* with different proportions of water, are usually sold under the name of *alcohol*, or of *rectified spirit of wine*.

Pure alcohol, or, as chemists usually call it, *absolute alcohol*, is commonly obtained by submitting rectified spirit to careful distillation, along with certain sub-

stances having a strong affinity for water; such as quicklime, dry carbonate of potassa, anhydrous sulphate of soda, or sulphate of copper, or fused chloride of calcium. Any of these answer when the operation is very cautiously conducted; the vapour of the absolute alcohol passes off and is condensed in a proper apparatus; and the water is so retained by the matters mentioned, that none of its vapour is blended with that of the alcohol.

Pure or absolute alcohol has an agreeable odour, and a strong pungent taste. It is limpid and colourless; and its specific gravity, at the temperature of 60°, is 0·794 (that of distilled water, at the same temperature, being assumed as 1·000). It has never been frozen. Its boiling point (under a barometrical pressure of 29·5 inches) is about 173°; and the specific gravity of its vapour (in reference to atmospheric air, as = 1·000) is 1·603. It is so expansile by heat, that 1000 measures, at 50°, become 1079 measures at 170°. It has a strong affinity for water, and gradually absorbs watery vapour when exposed to the atmosphere. When mixed with water, heat is at first evolved, and a considerable *diminution of bulk* ensues. If we mix 1000 measures of alcohol with 1162 of water, we do not obtain 2162 measures of the mixture, but only 2126; so that the diminution of bulk amounts to 36 measures; the alcohol and water are thus sometimes said to *penetrate* each other.

Alcohol is highly inflammable, burning with a very pale, bluish, smokeless flame; and it produces, during its

combustion, carbonic acid and water; every 100 parts of alcohol thus burned yielding about 136 parts of water; so that if a clean, cool, dry bell-glass, be held over the flame, it becomes abundantly bedewed.

Such are the properties of *pure alcohol;* when it is more or less diluted with water, these properties are of course proportionately modified; and it is in this diluted condition, that alcohol occurs in commerce. *Rectified spirit of wine,* for instance, has a specific gravity of about 0·835, and boils at about 180°; and what is called *proof spirit,* has a specific gravity of 0·919 at 60°, and contains, by *weight,* 49·24 parts of absolute alcohol, and 50·76 of water; or, *by measure,* 1000 parts of absolute alcohol, and 818 of water; which is very nearly in the proportion of 55 and 45 *per cent.* This is the *proof spirit of commerce;* and the strength of other spirituous liquors is frequently spoken of, in commercial language, as being so much *above,* or so much *under* proof; absolute alcohol might thus be said to be about 75½ above proof.

You will observe, from what I have now stated, that there are two denominations of what may be called spirituous or alcoholic liquors, in common use; namely, those which are the *primary produce of fermentation,* such as beer, cider, wine, and so forth; and those obtained by the *distillation* of the former, such as brandy, rum, gin, whisky, &c. These two modifications of alcoholic products must not be confounded, in reference to their respective *strengths,* for the products of the *still* are always more mischievous in their effects, and are

possessed of more deleterious intoxicating powers, than those of the *vat;* hence it becomes necessary to draw a line of distinction between beer, wine, and spirit drinkers.

It will be seen by the table already referred to, that the proportion of alcohol in beer is so small, that it can scarcely, in the usual acceptation of the term, be called an alcoholic liquor; and although, no doubt, the stronger kinds of beer, when taken in large quantities, may and do intoxicate, they at the same time involve such quantities of other matters, as materially interfere in their effects with those abstractedly belonging to the alcohol. Let us see how the matter stands in reference, for instance, to the stronger wines, and the stronger beers. A bottle of port wine, or rather I should say, a *quart* of port wine (for what is usually called and produced as a *bottle* of wine, is, in reality, very little more than an honest pint), contains, upon an average, about 20 *per cent* of alcohol; the strongest beers contain, upon an average, about 6 *per cent*—that is, when they are genuine, and as they issue from the brewery; for when once they have traversed the retailer's cellars, there is no saying what degree of dilution, or of other sophistication, they may have undergone. And as respects brandy, gin, and so forth, as they usually occur in trade, they may be said to contain at least 50 per cent. of alcohol. Now, there are, in these degenerate days, few persons who are not somewhat overpowered by a bottle of port,—not drunk perhaps, but somewhat approaching to it; and if we take a quart of port wine

as our standard of comparison, and call it a *maximum* dose, it is equivalent to about 8 ounces of alcohol, or to 16 ounces of brandy. Now this quantity of alcohol, if taken at once, and alone, would of course be fatal; so even might the 16 ounces of brandy; but if we reduce their respective strengths to the equivalent of port wine, by adding 32 ounces of water to the 8 of alcohol, or 24 ounces of water to the 16 of brandy, assuming our quart bottle of port to contain 40 fluid-ounces, we should still find that the alcohol and the brandy, thus respectively diluted, would still be more potent, more inebriating, and more hurtful to the constitution, than the port wine, although the *alcoholic contents* of the three liquors have been reduced to one and the same standard. Now, if the alcohol or the brandy of which we have just spoken, be drunk almost immediately after having been diluted with water, and before that *mutual penetration* of the two liquids to which I have adverted has attained its maximum, and it requires *several hours* for this purpose, it would on that account be more active; but the principal cause of the difference in effect lies in this, that when once the alcohol has been separated from a fermented liquor by the process of distillation, it never again enters into the same intimate state of union, or combination, with the other materials, as that which pre-existed in the original wine. I made this experiment:—I took a pint of sherry, and very carefully distilled from it half a pint of dilute alcohol,—of *brandy* in fact; I then mixed this brandy, or dis-

tilled wine, with the residue remaining in the retort, shook them well up together, and allowed the mixture (which ought to have corresponded with the original sherry), to remain a month in a well corked bottle; but neither in flavour, nor in effect, did it correspond with the original wine. Its taste was quite different, and it was more heating—less agreeable, in fact, to the stomach. There can, I think, be no doubt that distilled spirits, reduced to the same strength as wine, are more hurtful than wine to the constitution. Exceptions there are, no doubt, to this statement; but it will be found generally true. In wine, the alcohol is in some peculiar state of intimate combination with the water, acids, extractive, and other matters, which modify its characters and effects.

The same observations apply, though less remarkably, to the weaker wines; and as respects ale and porter, the quantity of alcohol which they contain is comparatively so small, that a very large quantity of those beverages is required to intoxicate. They are nutritive, from the amount of saccharine, mucilaginous, and extractive matters present in them; and perhaps the hops render them soporific: but these other matters so dilute their alcoholic contents as to render the latter comparatively insignificant; and I am convinced that many of the bad effects attributed to beer do not belong to the genuine product of the brewery, but must be ascribed to the narcotics of the sophisticators. The strongest beers, as they come direct from the great brewers, do not contain more than six per cent. of alcohol; a quart of

very strong ale may therefore contain two ounces and a quarter of alcohol; this alcohol, consequently, is diluted with between 37 and 38 ounces of water. Although, therefore, it be true that four quarts of ale contain the same quantity of alcohol as one quart of the stronger wines, the great amount of *dilution* sustained by the alcohol in beer must always be borne in mind; and those who seek for the cause, or the supposed cause, of the mischievous effects of beer, must look for it in some other ingredient than alcohol. The evil influences of alcohol are in inverse proportion to its state of dilution; brandy is more hurtful than wine, and wine than beer. As regards the great practical and popular results of this question, they lie between gin and beer; and Hogarth's celebrated contrast of Gin Lane and Beer Alley is no very exaggerated representation of their respective effects.

I think I have now said enough upon this part of my subject, and shall therefore proceed to the only remaining points which I have left untouched, and which relate to certain theoretical views bearing upon the composition of alcohol.

Alcohol, as already stated, is a ternary compound of carbon, hydrogen, and oxygen, in the following proportions, viz.:—

Carbon	52·18
Hydrogen	13·04
Oxygen	34·78
Alcohol	100·00

But I have spoken of the *atomic composition* of alcohol, a subject which has given rise to much important discussion, and upon which a few words will not here be misplaced.

Reverting to the lecture on the hydrocarbons, I showed you a table of them, which, amongst many others, included the following,—namely, olefiant gas, etherine, and ethyle; and I showed you how, by means of the action of sulphuric acid at an elevated temperature (namely at the temperature of 325°), we might resolve alcohol into water and olefiant gas. Now, using the same form of apparatus as that which I then employed, but *lowering the temperature of the boiling acid* from 325° to 300°, we resolve alcohol into *ether* and water. I have no time to enter into a detailed account of ether, but, as far as its atomic composition is concerned, it may be represented as constituted of 4 atoms of carbon, 5 atoms of hydrogen, and 1 atom of oxygen. Now alcohol is a compound of 4 atoms of carbon, 6 of hydrogen, and 2 of oxygen; so that by abstracting from alcohol 1 atom of hydrogen and 1 atom of oxygen, or, in other words, 1 atom of *water*, we leave ether; as in this diagram:—

Alcohol	$C_4H_6O_2$
Water	HO
Ether	C_4H_5O

If, now, from ether we abstract an atom of water, we leave *etherine*, C_4H_4, which you will remember is

isomeric with olefiant gas, C_2H_2; 1 atom of etherine representing 2 atoms of olefiant gas.

Ether	C_4H_5O
Water	H O
Etherine	C_4H_4

Such, then, are the relations of alcohol to olefiant gas and to ether. Ether itself, you observe, is a compound of 4 atoms of carbon, 5 atoms of hydrogen, and 1 atom of oxygen; that is, it is an *oxide of an hydrocarbon, consisting of 4 atoms of carbon and 5 atoms of hydrogen;* now this hydrocarbon, C_4H_5, we have elsewhere called *ethyle*; ether therefore, under this aspect, is an *oxide of ethyle.* This view of the subject was for a long time purely hypothetical, inasmuch as ethyle had never been isolated; but, thanks to the tact of Mr. Frankland, ethyle is no longer an unknown radical; he has obtained it in a separate and gaseous state, and has ascertained its properties and composition.

Ethyle, then, is a radical hydrocarbon, composed of 4 atoms of carbon, and 5 atoms of hydrogen; *ether* is an *oxide of ethyle;* and *alcohol* is a *hydrated oxide of ethyle.*

Such, then, is a sketch, a very hasty and imperfect sketch, of the phenomena and products of vinous fermentation; a process in which sugar is resolved into carbonic acid and alcohol; alcohol being a hydrate of ether; and ether, an oxyde of *ethyle*, which, like other

oxides, combines with the oxyacids, to form what may be termed the *salts* of ether; and in which, the oxygen is susceptible of replacement by chlorine, iodine, bromine, or cyanogen; that is, by the *halogens* generally, so as to form haloid combinations.

Other views of the atomic constitution of alcohol and ether have been propounded, but they are more hypothetical and less theoretical, and in my mind much less satisfactory and useful, than those which I have endeavoured to place before you.

When wine, beer, and other similar liquors, in which vinous fermentation has ceased, are *exposed to the access of air* at a due temperature, a new fermentation ensues, in which *oxygen is absorbed,* and the alcohol gradually passes into *acetic acid.* This is *acetous fermentation;* and its history embraces that of the manufacture of *vinegar.* Now, *anhydrous acetic acid,* which is the base of vinegar, is composed of 4 atoms of carbon, 3 atoms of hydrogen, and 3 atoms of oxygen; so that alcohol in passing into acetic acid, has lost 3 atoms of hydrogen and acquired 1 atom of oxygen, as shown in this table:—

Alcohol . . .	$C_4H_6O_2$
Acetic acid . . .	$C_4H_3O_3$

In other words, *ethyle,* C_4H_5, by the abstraction of 2 atoms of hydrogen, passes into *acetyle;* and *acetyle,* C_4H_3, by combining with 3 atoms of oxygen, becomes *acetic acid.*

And now I must bring these lectures to an end. I have endeavoured, in this Course, to show the intimate relations that subsist between abstract science and the useful arts—between the refinements of modern chemistry, and the improved and extended condition of some of our leading manufactures; and having brought it to a conclusion, I must take my final leave. I may truly say, that I unwillingly resign my Professorship; but the attacks of inflammatory hoarseness, to which I have been subject, have of late so much interfered with my duties here, and are so manifestly aggravated by any exertion of voice, as to render the measure one, if not of necessity, at least of prudence.

In the year 1812, when Sir Humphry Davy retired from office, I was desired by the Managers of this Institution to prepare a probationary course of lectures, which I delivered at this table in the spring of 1813, and was immediately after elected to fill the vacant chair; so that I have been officially attached to the Royal Institution, for a period of forty years. During the greater part of that time, namely, from 1815 to 1848, I also delivered a series of lectures and demonstrations on theoretical and practical chemistry in the Laboratory below. They were intended for all denominations of students, and were given at nine in the morning, thrice weekly, from the beginning of October to the end of May. They were the first lectures in London in which so extended a view of chemistry and of its applications, including technical, mineralogical, geological, and medical

chemistry, was attempted; and I look back on them with much satisfaction, because I think I may fairly claim for them the merit of having completed the scheme and added to the usefulness of this Institution—of having helped to diffuse that knowledge and that love of the science now so general—of having done so amongst all grades and classes of students—of having, therefore, fulfilled one of our principal objects.

As to the lectures in this Theatre, I must not pretend to conceal from you that I relinquish *them* with regret. The teaching of chemistry here has always been a delight to me; and to have successfully taught it for so extended a period, and to such an audience, has been, and indeed can be, the privilege of a very few; and believe me, I duly appreciate it; and that I look back with feelings that I cannot represent in words, at the confidence which successive Managers of this Institution have placed in me, and at the uninterrupted kindness and attention with which my imperfect endeavours to set forth the truths of chemical science in their varied relations, as evidences of the wisdom, power, and beneficence of the Creator, on the one hand, and, on the other, as regards their multifarious bearings upon the sister sciences and upon the useful arts, have been received.

There are also other considerations which necessarily press themselves upon me at the present moment, arising out of the retrospect of the very large portion of my life which has been passed within these walls, and as an officer of this establishment. I rejoice in leaving it in

all respects more prosperous than at any former period; its scientific fame more pre-eminent; its foundations more secure; its halls more frequented; its usefulness more acknowledged; and I cannot help discerning in this Institution one fertile source of that popularity of science, and extension of schools for scientific instruction, which so peculiarly distinguishes the present age, and has more especially manifested itself in this mighty metropolis.

Looking *personally* at the Royal Institution, I revere it as my *alma mater*, where, as a school-boy, I listened to the fruitful eloquence of Davy, and afterwards partook of his acquaintance and friendship; where I acquired the patronage of Sir Joseph Banks; where I was singled out by Wollaston as his successor in the Secretaryship of the Royal Society; where I came into frequent contact with the chiefs of science, and of literature and art—where Faraday became my pupil, my colleague, and my friend. These, I assure you, are only a very few of the proud and pleasing reminiscences which accompany me from this place; and they are unsullied and unalloyed; they have never been clouded, tainted, or embittered. I again therefore thank you for all your partiality and kindness; and, in gratitude to Providence, in whose merciful hands are all the issues of our lives, I respectfully beg you to accept my affectionate farewell.

PETTER AND GALPIN, PLAYHOUSE YARD, ADJOINING THE "TIMES" OFFICE.

00088112

Digitized with financial assistance from the
Government of Maharashtra
on 09 March, 2016